GENDERED IMPACTS OF CLIMATE CHANGE: EMPIRICAL EVIDENCE FROM ASIA

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CONTENTS

1.INTRODUCTION

The effects of climate change, such as changes in temperatures, precipitation and biodiversity loss, are affecting human health, food security and livelihoods,[1] as well as the quality and availability of land, water and other natural resources. As individuals are intrinsically linked to their environment, climate change poses a serious threat to every aspect of human life. It has been long recognized that the consequences of climate change are not experienced evenly, and women – who are less likely than men to own productive assets and are more dependent on natural resources for their livelihoods – are likely to be disproportionately affected.[2] Social norms often put women in charge of gathering food, collecting water and fetching fuel for cooking and heating – chores that are increasingly time-consuming as climate change affects the availability and quality of these resources. Women's capacity to cope with the effects of climate change is also hindered by their overall disadvantage: they are overrepresented among the poor, face barriers to decision-making, experience disproportionate mobility challenges and face unequal access to resources.

To put in place inclusive strategies that increase the resilience of women and men in all their diversity, there is an urgent need to better understand the gendered effects of climate change across countries. To achieve this, this paper explores the connections between phenomena related to climate change and gender related outcomes in Bangladesh, Cambodia, Nepal, the Philippines and Timor-Leste. In particular, it tests these associations by utilizing random forest machine learning techniques and binary logistic regression analysis, on a data set that integrates data from Demographic and Health Surveys (DHS) and geographical information systems (GIS).

Findings suggest that climate-related factors are statistically associated with gender related outcomes in all five countries, even after controlling for socioeconomic variables such as wealth, education and age. As expected, the clearest connections are found with the availability of clean water and fuel in households, thus highlighting that increases in relative aridity, temperatures, the risk of floods and the frequency of droughts may impact women's fuel and water collection burdens across all countries considered. Strong associations were also observed between these climate related variables and child marriage and adolescent births, particularly in countries such as Bangladesh, Nepal or Cambodia, where social norms support these practices overall. Connections between climate related variables and the prevalence of intimate partner violence were milder and differed across countries.

These findings demonstrate the potential consequences that climate change may have on gender equality and women's empowerment. They are a warning sign that the two issues cannot be addressed in isolation, and they shed light on the important data gaps hindering further analysis in this regard, including intersectional and multidimensional analysis that truly captures the complexity of these relations.

[1] IPCC (2014). Climate Change 2014: Impacts, Adaptation, and Vulnerability. Available from: www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-PartA_FINAL.pdf.

[2] UN Women (2015). The Beijing Declaration and Platform for Action Turns 20. https://www.unwomen.org/en/digital-library/publications/2015/02/beijing-synthesis-report

2.BACKGROUND

According to the Intergovernmental Panel on Climate Change (IPCC), climate change refers to a change in the state of the climate that can be identified by changes in the mean climate and/or the variability of its properties, and that persists for an extended period, typically decades or longer.[3] The negative impacts of climate change have become increasingly evident, including long-term changes in average temperature; changes in the intensity, timing and geographical variation of rainfall; and increases in the frequency and severity of drought episodes and floods.[4] While the impacts are far reaching, not everyone is affected equally. Climate change impacts are differently distributed among different regions, generations, age classes, income groups, occupations and genders.[5]

Women are highly vulnerable to these impacts. Recent studies offer country-specific insights into how women's lack of access to and control over basic resources and other pre-existing disadvantages exacerbate how they are impacted by climate change and undermine their ability to cope. For instance, in India, child marriage rates were found to increase after rainfall shocks,[6] while in Bangladesh a higher number of dry months were significantly found to increase these rates.[7] Another study found that droughts had an adverse effect on the body mass index of rural women in Zimbabwe, but men were not as affected.[8]

The literature points to a number of possible factors contributing to these associations, ranging from poverty-driven inadequate means of adaptation[9] to reduced coping capacities dictated by limited ownership of assets[10] and social norms putting women at a disadvantage (for example, women in Bangladesh were unable to evacuate flooded areas in the absence of a male chaperone due to travel restrictions).[11] Although existing research is useful in demonstrating some linkages between gender and climate change in specific contexts, it is, for the most part, single-country-focused. To inform cross-country recommendations, this study aims to test the hypothesis that changes in climate factors are associated with gender outcomes across the board (see detailed hypothesis in section 3. Methodology). Specifically, it tests the association between climate change and five development indicators that affect women in particular: 1) prevalence of child marriage; 2) adolescent birth rates; 3) prevalence of intimate partner violence in the past 12 months; 4) access to basic water sources; and 5) access to clean cooking fuel. A brief description of the rationale behind the selection of these indicators, along with a short literature review, is provided below.

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[3] See www.ipcc.ch/site/assets/uploads/2018/02/ar4_syr_full_report.pdf.
[4] Ibid.
[5] IPCC (2001). Climate Change 2001: Impacts, Adaptation and Vulnerability. Summary for Policymakers.
[6] L. Corno, N. Hildebrandt and A. Voena (2017). Age of marriage, weather shocks, and the direction of marriage payments. Working paper 23604. Available from: www.nber.org/system/files/working_papers/w23604/w23604.pdf.
[7] M. Tsaneva (2020). The effect of weather variability on child marriage in Bangladesh. *Journal of International Development*. Available from: https://onlinelibrary.wiley.com/doi/abs/10.1002/jid.3507.
[8] A. Goh (2012). A literature review of the gender differentiated impacts of climate change on women's and men's assets and well-being in developing countries. CAPRi Working paper No. 106. Available from: www.worldagroforestry.org/sites/default/files/4.pdf.
[9] G. O'Brien, et al. (2008). Climate adaptation from a poverty perspective. *Climate policy*, vol. 8, Issue 2, pp. 194–201. Available from: www.tandfonline.com/doi/abs/10.3763/cpol.2007.0430.
[10] A. Goh (2012).
[11] S. Crate and M. Nuttall (2016). *Anthropology and climate change: From encounters to actions*. New York: Taylor Francis.

2.1. Child marriage

Child marriage refers to any formal or informal union between a child under the age of 18 and an adult or another child. Child marriage affects personal agency and is known to result in poor educational attainment and heightened risk of adolescent births. While both girls and boys are victims of this practice, girls are most affected. The drivers are complex, with sociocultural norms, socioeconomic status, faith and education being key determinants.[12] Human insecurity and conflict are also risk factors for child marriage,[13] as are natural hazards, which aggravate poverty and may promote the use of child marriage as a coping strategy.[14] In Bangladesh, for instance, economic challenges exacerbated by climate change were found to be key drivers of child and forced marriages.[15]

2.2. Adolescent births

Childbearing during adolescence has health consequences for mother and child,[16] and may carry social and economic impacts, as young mothers are more likely to have lower pay later in life. Factors associated with adolescent births include young age at first marriage, lower educational attainment,[17] limited access to contraception, poorer knowledge of family planning, and lack of access to information and services.[18] In the aftermath of disasters, adolescent girls report higher levels of sexual harassment and abuse[19] and women and child refugees may be forced to have sex in exchange for food and shelter,[20] potentially resulting in adolescent births. Whether girls disproportionately affected by climate change are more likely to become adolescent mothers, remained largely unexplored in existing literature.

2.3. Intimate partner violence

Intimate partner violence (IPV) refers to any behaviour within an intimate relationship that causes physical, psychological or sexual harm to those in that relationship.[21] Multiple intersecting risk factors, ranging from educational attainment, age, acceptance of violence, social norms, legal protection, armed conflict and high levels

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[12] A. Malhotra, et al. (2011). Solutions to End Child Marriage: What the evidence shows; and J. Parsons, et al. (2015). Economic Impacts of Child Marriage: A review of the literature.

[13] A. Kohno, et al. (2020). Investigation of the key factors that influence the girls to enter into child marriage: A meta-synthesis of qualitative evidence. *PLOS ONE*. Available from: https://journals.plos.org/plosone/article/metrics?id=10.1371/journal.pone.0235959#citedHeader.

[14] D. Zoe (2020). Childhood and Well-Being in Bangladesh: A Focus on Gender Inequalities, Child Marriage and Climate Change Issues. *Plymouth Institute of Education Online Journal*; M. Asadullah, K.M. Islam and Z. Wahhaj (2020) Child marriage, climate vulnerability and natural disasters in coastal Bangladesh. *Journal of Biosocial Science*.

[15] M. Alston, et al. (2014). Are climate challenges reinforcing child and forced marriage and dowry as adaptation strategies in the context of Bangladesh? *Womens Studies International Forum*.

[16] S. Singh (1998). Adolescent childbearing in developing countries: A global review. *Studies in Family Planning*. Available from: www.jstor.org/stable/172154?seq=1.

[17] WHO (2014). Adolescent pregnancy: Situation in South-East Asia Region. Available from: https://apps.who.int/iris/bitstream/handle/10665/204765/B5164.pdf.

[18] E. Kennedy, et al. (2011). Adolescent fertility and family planning in East Asia and the Pacific: a review of DHS reports. *Reproductive Health*. Available from: https://reproductive-health-journal.biomedcentral.com/articles/10.1186/1742-4755-8-11.

[19] S. Bartlett (2008). Climate Change and Urban Children: Impacts and Implications for Adaptation in Low and Middle-Income Countries. *Environment and Urbanization*.

[20] T. Aryanti and A. Muhlis (2020). Disaster, gender, and space: Spatial vulnerability in post-disaster shelters. Earth and Environmental Science. Available from: https://iopscience.iop.org/article/10.1088/1755-1315/447/1/012012/pdf.

[21] WHO (2012). Understanding and addressing violence against women. Available from: https://apps.who.int/iris/bitstream/handle/10665/77432/WHO_RHR_12.36_eng.pdf;sequence=1.

of general violence in society are associated with IPV.[22] The literature, though sparse, suggests the existence of an association between alterations in temperatures and precipitation and the prevalence of violence. In particular, studies have proven these connections in drought-prone areas of sub-Saharan Africa (largely non-intimate partner violence).[23] Empirical cross-country evidence on this topic in Asia, however, is largely missing and inconclusive in existing literature.

2.4. Access to basic drinking water sources

Accessing basic drinking water sources is statistically defined as being able to use an improved water source located within 30 minutes, round trip, from the place of residence.[24] Because women and girls shoulder the burden of fetching water in 80 per cent of the world's households that lack it,[25] ensuring universal water access is key to women's empowerment. As changes in temperature and precipitation affect water availability and quality, women and girls may need to fetch water from more distant sources. Studies conducted in South Asia confirm the heightened stress on rural women as these regions experience severe water scarcity.[26] No such empirical literature was found for South-East Asia at the time of review.

2.5. Access to clean cooking fuel

To date, 3 billion people globally continue to rely on solid fuel such as wood and animal dung for cooking and heating.[27] Evidence shows that exposure to indoor air pollution and the burden of fuel collection disproportionately affect women, who spend more time at home and are often in charge of cooking and collection chores.[28] As climate change affects agricultural yield and other environment-related livelihoods, households are turning to inferior but cheaper fuel and altering cooking and collection patterns.[29] Little empirical evidence, however, exists to demonstrate how climate change affects women's fuel use and related health and time burdens across Asian countries.

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[22] T. Abramsky, et al. (2011) What factors are associated with recent intimate partner violence? Findings from the WHO multi-country study on Womens heath and domestic violence; Yount, et al. (2016); L. Ackerson and S.V. Subramanian (2016) State Gender Inequality, Socioeconomic Status and Intimate Parnter Violence in India: A Multilevel Analysis; M. Muluneh, Y.W. Alemu and M.W. Meazaw (2021) Geographic variation and determinants of help seeking behaviour among married women subject to intimate partner violence: evidence from national population survey.

[23] Hsiang, S.M., Burke, Marshall., and Miguel, E. (2013). Quantifying the influence of climate on human conflict. Available from: https://science.sciencemag.org/content/341/6151/1235367; and A. Epstein, et al. (2020). Drought and intimate partner violence towards women in 19 countries in sub-Saharan Africa during 2011–2018: A population-based study. *Plos Medicine*. Available from: https://journals.plos.org/plosmedicine/article?id=10.1371/journal.pmed.1003064.

[24] See https://washdata.org/monitoring/drinking-water.

[25] UN Women www.unwomen.org/en/news/in-focus/women-and-the-sdgs/sdg-6-clean-water-sanitation.

[26] S.S. Yadav and R. Lal (2018). Vulnerability of women to climate change in arid and semi-arid regions: The case of India and South Asia. *Journal of Arid Environments*. Available from: www.sciencedirect.com/science/article/abs/pii/S0140196317301532.

[27] See www.unwomen.org/en/news/in-focus/women-and-the-sdgs/sdg-7-affordable-clean-energy.

[28] See https://trackingsdg7.esmap.org/data/files/download-documents/tracking_sdg_7_2020-full_report_-_web_0.pdf.

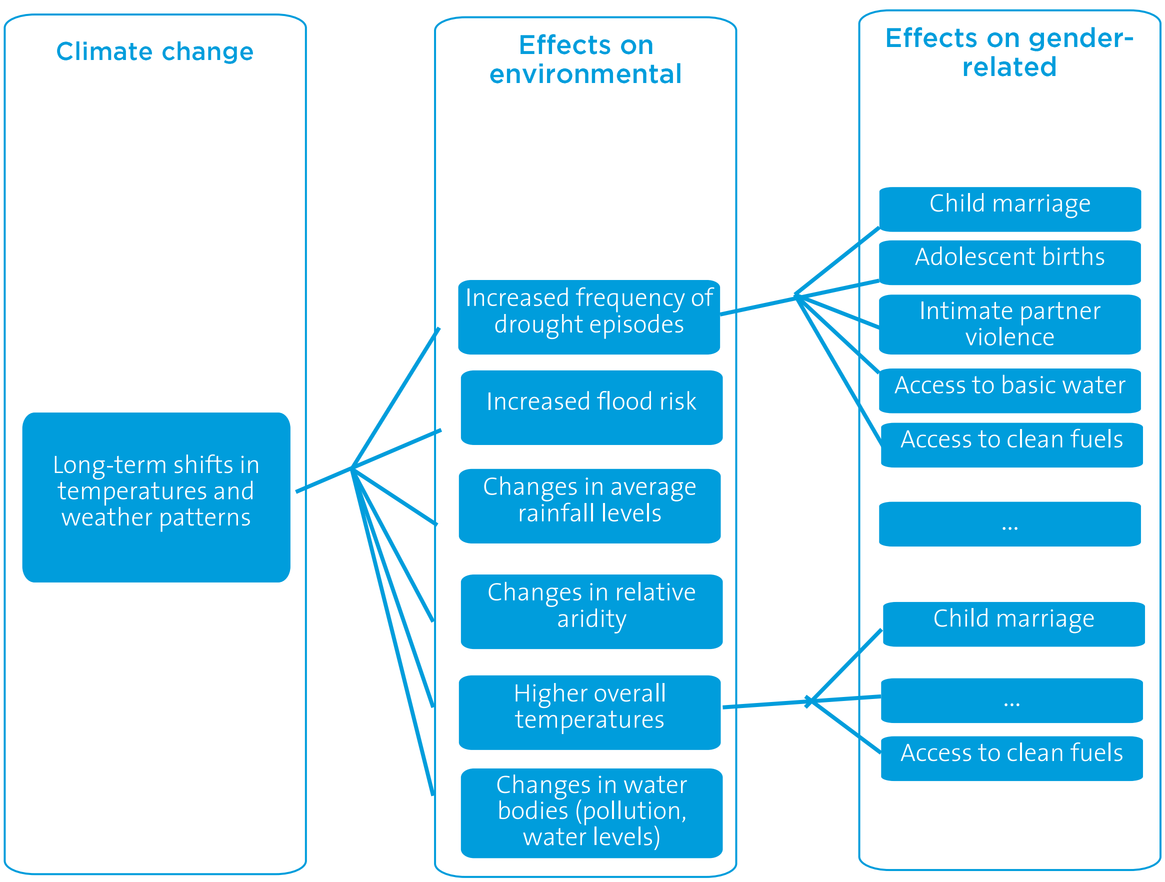
[29] I. Das, P. Jagger and K. Yeatts (2017). Biomass cooking fuels and health outcomes for women in Malawi. *Ecohealth*. Available from: www.ncbi.nlm.nih.gov/pmc/articles/PMC5357447/; and Oxfam (2002). *Gender, Development and Climate Change*. Available from: https://oxfamilibrary.openrepository.com/bitstream/handle/10546/121149/bk-gender-development-climate-change-010102-en.pdf.

3.METHODOLOGY

By empirically showcasing linkages between climate change and specific outcomes for women and girls across Asian countries, this study aims to confirm the following hypothesis:

Hypothesis: Changes in climate-related variables are associated with changes in outcomes for women and girls in Asian countries, as measured by five development indicators that affect women and girls in particular: child marriage rates; adolescent births rates; prevalence of IPV; access to basic drinking water sources; and access to clean cooking fuel.

FIGURE 1: Graphic depiction of hypothesis



Note: The hypothesis aims to test whether each of the climate/environment related variables is associated with changes in at least one gender outcome across countries. For ease of representation, not all gender related development indicators have been depicted next to each environmental variable.

In other words, the aim of this paper is to prove that variations in temperatures, precipitation, relative humidity and water bodies, among other variables, are connected with worsening gender related development indicators across Asian countries. The methodology used does not prove causality, but rather association. It is expected that these associations are facilitated by intermediate variables in some cases. For instance, changes in weather patterns may correlate with increases in child marriage rates via economic hardship among agricultural populations (e.g. a child's parents may resort to child marriage as a coping strategy to mitigate economic loss brought on by climate change). Similarly, adolescent birth rates may rise as a result of increases in child marriage.

DHS microdata[30] integrated with geospatial data from the DHS geospatial covariates data set, the Global Disaster Risk Dataset of the United Nations Office for Disaster Risk Reduction[31] and the Global Self-consistent, Hierarchical, High-resolution Geography Database[32] were utilized to test this hypothesis. The analysis was carried out with data from Bangladesh, Cambodia, Nepal, the Philippines and Timor-Leste. Three criteria were considered in the process of selecting these countries: 1) the selected countries are highly affected by climate change, in terms of frequency of climate events, fatalities, economic losses or a combination thereof;[33] 2) both DHS microdata and geospatial data are available and publicly accessible; and 3) the selected countries are sufficiently different from each other (from an environmental point of view) to add variability to the analysis, while keeping geographical representation across subregions in Asia.

TABLE 1: Characteristics of surveys considered

Name	Clusters	Women sample size
DHS Bangladesh 2017*	675	21 289
DHS Cambodia 2014	611	17 578
DHS Nepal 2016	383	11 294
DHS Philippines 2017	1 250	25 074
DHS Timor-Leste 2016	455	12 607

* The latest DHS survey in Bangladesh did not collect information on time to water source, thus the indicator on access to basic water sources has been calculated using DHS 2014.

TABLE 2: Time period of key geospatial variables

Country	Drought episodes*	Aridity index	Daytime land surface temperature	Rainfall	Riverine flood risk	Proximity to lake	Proximity to coastline
Bangladesh	1980–2000	2015	2015	2015	2015	2017	2017
Cambodia	1980–2000	2015	2015	2015	2015	2017	2017
Nepal	1980–2000	2015	2015	2015	2015	2017	2017
Philippines	1980–2000	2015	2015	2015	2015	2017	2017
Timor-Leste	1980–2000	2015	2015	2015	2015	2017	2017

30 DHS Individual Recode files were used as they include women's responses along with some household variables of relevance. In Bangladesh, where only ever-married women were interviewed through the women's questionnaire, the individual recode and person recode datasets were merged to incorporate information on unmarried women. No information from men recodes was utilized for this analysis, as it is not necessary to test the hypothesis (the outcomes considered are gender relevant without sex disaggregation).
31 See https://risk.preventionweb.net/capraviewer/.
32 Global Self-consistent, Hierarchical, High-resolution Geography Database. Available from: www.soest.hawaii.edu/pwessel/gshhg/.
33 See https://germanwatch.org/sites/default/files/Global%20Climate%20Risk%20Index%202021_2.pdf.

* Drought estimates are obtained from the DHS geospatial covariates data set and are based on 1980–2000 precipitation data. Note: The names of geospatial covariates have been shortened for ease of reference. Refer to Table 4 for further details.

3.1. Variables

For this analysis, the five gender related development indicators listed in the hypothesis are the key dependent variables (table 3), with seven factors related to climate change as independent variables (table 4). Since many socioeconomic factors are also likely to influence gender equality, eight control variables were included in the model.

All dependent variables were constructed as dichotomous categorical variables.

TABLE 3: Dependent variables

Variable	Calculation from survey data	Notes
Child marriage rates	Women whose age at first marriage or cohabitation was lower than 18*	Women under age 18 were removed from the sample†
Adolescent birth rates	Women whose first live delivery took place before they turned 18‡	
Prevalence of intimate partner violence in the past 12 months	Women who experienced physical (severe or less severe) or sexual violence from an intimate partner in the 12 months preceding the survey**	A 12-month reference period was deemed preferable over lifetime experiences given the increasing variability in weather patterns in recent years.
Lack of access to basic drinking water sources	Women living in households that lack piped water (into their dwelling or yard), or other improved sources such as public standpipes, tube wells, boreholes, protected wells, rainwater or bottled water, within a 30-minute round trip	Considered as a proxy measure for water collection-related time and health burdens
Lack of access to clean cooking fuel	Women living in households that use unhealthy cooking fuel, such as kerosene, charcoal, wood, straw/shrubs/grass, agricultural crops, or animal dung	Considered a proxy measure for the health effects of cooking and fuel collection burdens

* In Bangladesh only data for formal unions was available.
† The reference age group for this indicator differs from that of SDG indicator 5.3.1, which considers women ages 20–24 who married before age 18.
‡ The reference age group for this indicator differs from that of SDG indicator 3.7.2, which considers women ages 10–14 and 14–19.
** DHS Bangladesh did not include information on IPV, so the country was not considered for IPV analysis.
All independent variables were obtained from geospatial data sets and no further calculations were conducted, with the exception of proximity to water bodies, for which the variable was disaggregated into distance to lakes and distance to marine coastlines.

TABLE 4: Independent variables

Variable	Definition	Environmental correlations
Daytime land surface temperature	Mean annual daytime land surface temperature (skin temperature) within a 2 km (urban) or 10 km (rural) buffer surrounding the survey cluster (°C).	It is linked with forest transition, land degradation, biodiversity loss[/a] and reduction of global crop yields.[/b] It influences the rate and timing of plant growth[/c] and may vary widely between urban areas and forest covered regions, because it is affected by the exchange of energy and water between the land surface and the atmosphere.
Drought episodes	Periods when the magnitude of monthly precipitation is less than or equal to 50 per cent of its long-term median value for three or more consecutive months.[/d] Values are categorical and range between 1 (low frequency of drought episodes) and 10 (high frequency of drought episodes).	The increased frequency and severity of drought episodes is known to have effects on agricultural yield, quality of water and air, as well the proliferation of disease.[/e]
Average annual rainfall	Average amount of rain (mm) per year. Rainfall data build on interpolation techniques and high-resolution imagery, with long period of record precipitation estimates based on infrared cold cloud duration observations.[/f]	Changes in rainfall are known to affect agricultural yield and biodiversity loss, among others. With the progression of global warming, the hydrological cycle is projected to intensify.[/g] This may affect freshwater quality as well.
Aridity index	Calculated as the average yearly precipitation divided by average yearly potential evapotranspiration, it is a measure of the drying power of the atmosphere to remove water from land surfaces by evaporation (e.g. from the soil and plant canopy) and via plant transpiration.[/h] Values range between 0 and 300, with higher values indicating more humid conditions (low evapotranspiration) and lower values	Increases in temperatures and loss of forest cover, among other factors, contribute to aridification, which leads to agricultural loss,[/i] heightened food insecurity, reduced water quality and biodiversity loss.[/j]

	indicating more arid conditions (high evapotranspiration).	
Probability of riverine flood	Estimated probability of major river basins flooding in 50 years. It is modelled by dividing the global landmass into water catchments, on which stream flows are projected. This generates information on the peak flows and their frequencies, which are used to model downstream water levels, and determine stochastic event-sets (unpredictable events) of riverine floods, from which hazard maps are obtained for 50 years.[/k]	Floods affect agricultural yield, support water borne disease[/l] and may affect infrastructure.
Proximity to water bodies	Geodesic distance of the cluster to either a lake or marine coastline (m). As the effects of proximity to fresh water sources may be different from those of proximity to oceans, the variable was split into two.	As the availability and quality of water bodies changes, proximity has implications for drinking water quality, salinization of agricultural land, and issues with food security, among others.[/m]

[/a] Darren How Jin Aik, et al. (2021). Evaluating the impacts of land use/land cover changes across topography against land surface temperature in Cameron Highlands. *PLOS ONE*. Available from: www.ncbi.nlm.nih.gov/pmc/articles/PMC8139479/.
[/b] C. Zhao, B. Liu and S. Piao (2017). Temperature increase reduces global yields of major crops in four independent estimates. *Proceedings of the National Academy of Sciences*. Available from: www.pnas.org/content/114/35/9326.
[/c] See https://climate.esa.int/en/projects/land-surface-temperature/about/.
[/d] See https://sedac.ciesin.columbia.edu/data/set/ndh-drought-hazard-frequency-distribution.
[/e] See www.cdc.gov/nceh/drought/implications.htm.
[/f] B. Mayala, et al. (2018). The Geospatial Covariate Datasets Manual. Available from: http://spatialdata.dhsprogram.com/references/DHS%20Covariates%20Extract%20Data%20Description%202.pdf
[/g] H. Tabari (2020). Climate change impact on flood and extreme precipitation increases with water availability. *Scientific Reports*. Available from: www.nature.com/articles/s41598-020-70816-2.
[/h] See https://wad.jrc.ec.europa.eu/patternsaridity
[/i] I. Tereshchenko, et al. (2015). Changes in Aridity across Mexico in the Second Half of the Twentieth Century. *Journal of Applied Meteorology and Climatology*. Available from: www.researchgate.net/publication/283184307_Changes_in_Aridity _across_Mexico_in_the_Second_Half_of_the_Twentieth_Century.
[/j] W. Hu, et al. (2021). Aridity-driven shift in biodiversity–soil multifunctionality relationships. *Nature communications*. Available from: www.nature.com/articles/s41467-021-25641-0.
[/k] R. Rudari, et. al., (2015). Improvement of the global flood model for the GAR 2015.
[/l] K.F. Cann, et al. (2013). Extreme water-related weather events and waterborne disease. *Epidemiology and Infection*. Available from: https://pubmed.ncbi.nlm.nih.gov/22877498/.
[/m] FAO. (2015). Climate change and food security: risks and responses. Available from: https://www.fao.org/3/i5188e/I5188E.pdf .

Control variables, identified through the literature review, were included to account for non-climate related factors that could potentially affect gender related development indicators. The control variables include: educational attainment in single years; women's employment status at the time of the survey; age; wealth quintiles (based on DHS wealth index); household location (urban/rural); built up index (degree of urbanization at the cluster level); proximity to national borders; and proximity to protected areas (such as national parks, national forests and national seashores). These variables were all held constant in the models to assess the individual effect of each of the other variables on the gender related development indicators.

3.2. Statistical models

First, a random forest analysis, a machine learning technique, was utilized to test the relevance of each of the independent variables to explain the gender outcomes in each country. Random forest evaluates the impact of removing the climate variables (and the control variables) one by one on the accuracy of the overall model. The algorithm uses a collection of decision trees to perform classification or regression tasks. As such, it computed multiple decision tress for classifying the risk of an outcome, for instance child marriage, taking place when each climate phenomena was present or absent.

Additional correlation and regression analysis followed to test the direction and strength of associations. The results of univariate analysis (Annex 1), as well as the correlations between all independent and dependent variables (Annex 2) and among all independent variables (Annex 3) show degrees of association and lack of multicollinearity. Scatterplots (Annex 4) were followed by multivariate binary logistic regression (box 1).

While multivariate binary logistic regression models focus on estimating associations between dependent and independent variables, random forest focuses on classification[34] (e.g. mean decrease in the model's accuracy upon exclusion of each variable[35]) and thus, findings may differ.

BOX 1: Understanding the gender-climate associations through multivariate binary logistic regression

The multivariate binary logistic regression model can be described as:

$$\log[\frac{P}{1-P}] = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \cdots + \beta_i X_i$$

Where:

- *P* is the probability of the dependent variable (i.e., the gender related development indicator) adopting a value of 1, and thus 1-*P* is the probability of it adopting the value of 0.
- The ratio of *P* and 1-*P* represents the odds ratio in favour of the dependent variable's occurrence, (i.e., whether a woman will be married before 18 years of age, whether she will have a child during adolescence, etc.).
- X_1 to X_i are all the independent variables being considered, including the climate change related variables and control variables.
- The β parameters are a set of coefficients (to be estimated) that refer to the effect of independent variables on the log odds, such that the dependent variable is equal to 1, controlling for all other independent variables.

The model-fitting process ran a null model first, with only the intercept (β_0) and no independent or control variables. The second model included all key independent variables (e.g. climate related). The comparison of The Residual Deviance (RD) and Akaike Information Criterion (AIC) values of both models produced unadjusted odds ratios, which were then adjusted using the RD and AIC values of a third model with all independent variables and control variables. The generalized linear model function in R (version 4.0.2) was used for this analysis.

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[34] R. Couronne, P. Probst and A. Boulesteix (2018). Random forest versus logistic regression: a large-scale benchmark experiment. *BMC Bioinformatics*. Available from: https://bmcbioinformatics.biomedcentral.com/articles/10.1186/s12859-018-2264-5.
[35] F. Martinez-Taboada and J.I. Redondo (2020). Variable importance plot (mean decrease accuracy and mean decrease Gini). *PLOS ONE*. Available from: https://doi.org/10.1371/journal.pone.0230799.g002.

4. LIMITATIONS

For this analysis, variables related to climate change have been observed over the course of roughly one year.[36] In most countries, the reference year from the GIS data differs from the reference year for the survey microdata. Thus it is impossible to study direct impacts of select weather events on a population group, and no direct causation can be attributed. Rather, the analysis aims to ascertain whether geographical areas and population groups that typically suffer from the recurrent effects of climate change are more likely to experience overall changes in gender outcomes.

An additional limitation is associated with the fact that the latest available DHS data used for this analysis is a few years old (2014–2017). As some climate related phenomena change rapidly, more up-to-date information would be better suited to provide a more accurate picture of the current situation.

The localized nature of environmental events and related coping capacity poses additional challenges to draw cross-country conclusions. In other words, because droughts, floods and other events related to climate change may differ in magnitude, duration, intensity, etc. across municipalities, neighbourhoods and even dwellings, and because people's capacity to cope may differ based on a wide variety of factors (e.g. asset ownership, access to finance, availability of public services, inheritance rights, existing infrastructure, cost of resources, suddenness of the event, availability of early warning systems, access to decision-making structures, etc.) data analysis at the country level in the reference period may not always show conclusive results across all countries. As such, the combination of findings from both logistic regression and random forest models must be considered in tandem to understand the different degrees in which climate related variables contribute to gender outcomes.

The choice of dependent variables (the five gender related development indicator representing the outcomes) was somewhat restricted by data availability. It would have been ideal to consider the effects of climate variables on issues such as the time spent collecting fuel or fetching water, but the unavailability of comparable data across the selected countries made this impossible, which resulted in the inclusion of indicators on access to basic water sources and clean cooking fuel instead. Similarly, controlling for asset ownership, availability of public services in a particular area, quality of infrastructure, fuel and water prices, or whether weather events took place out of season, was not possible due to limited data availability. In this regard, additional analysis is necessary to further explain some of the results.

Findings from the random forest and logistic regression models do not always agree on which climate variables are most relevant for predicting gender outcomes. This is because they each serve a different purpose. While logistic regression identifies the odds of an increase in a gender related outcome given a one unit increase in a climate variable (direct or inverse associations), random forest highlights the reduction in the model's accuracy if a climate related variable was removed. Therefore, a variable such as proximity to coastlines, which may have a positive effect on populations with fishery-related livelihoods but a negative effect on agricultural population due to salinization,

[36] The reference period for all DHS variables is one year. Most geospatial covariates also refer to a single year (2014/15), except for drought data, which refer to 1980–2017.

may appear to have little effect in a logistic regression model of a country as a whole, but random forest will still show high classification power (e.g. is good at identifying the risk of each gender related outcome among different population groups. In addition, while logistic regression performs well in models where explanatory variables have large variances, random forest returns higher true positive rates for data sets with numerous noise variables.[37] Issues such as non-linear relations between variables,[38] the imbalanced nature of flood and water related data sets[39] and multicollinearity[40] may also prevent the binary logistic regression model from picking up on associations that random forest is able to capture.

5. FINDINGS

Both the random forest and logistic regression models found that climate related variables were important to explain outcomes for the five gender related development indicators. The explanatory power of each variable on each of the development indicators differed across countries, as did the direction and strength of associations, although some commonalities are clear.

5.1 All climate-related variables considered are powerful at classifying the risk of gender outcomes

The random forest analysis showcased the relevance of each climate related variable on predicting the risk of gender inequalities (all climate variables contribute significantly to the model's accuracy), and thus support the hypothesis. In particular, findings suggest that across countries all climate variables considered were highly relevant to explain the risk of lacking clean cooking fuel, and almost all (with the exception of drought episodes) explained substantially the lack of access to basic drinking water sources as well. The risk of child marriage was substantially explained by changes in average rainfall levels, relative aridity, temperatures and water bodies; while adolescent births saw high explanatory power on droughts, relative aridity and proximity to water bodies.

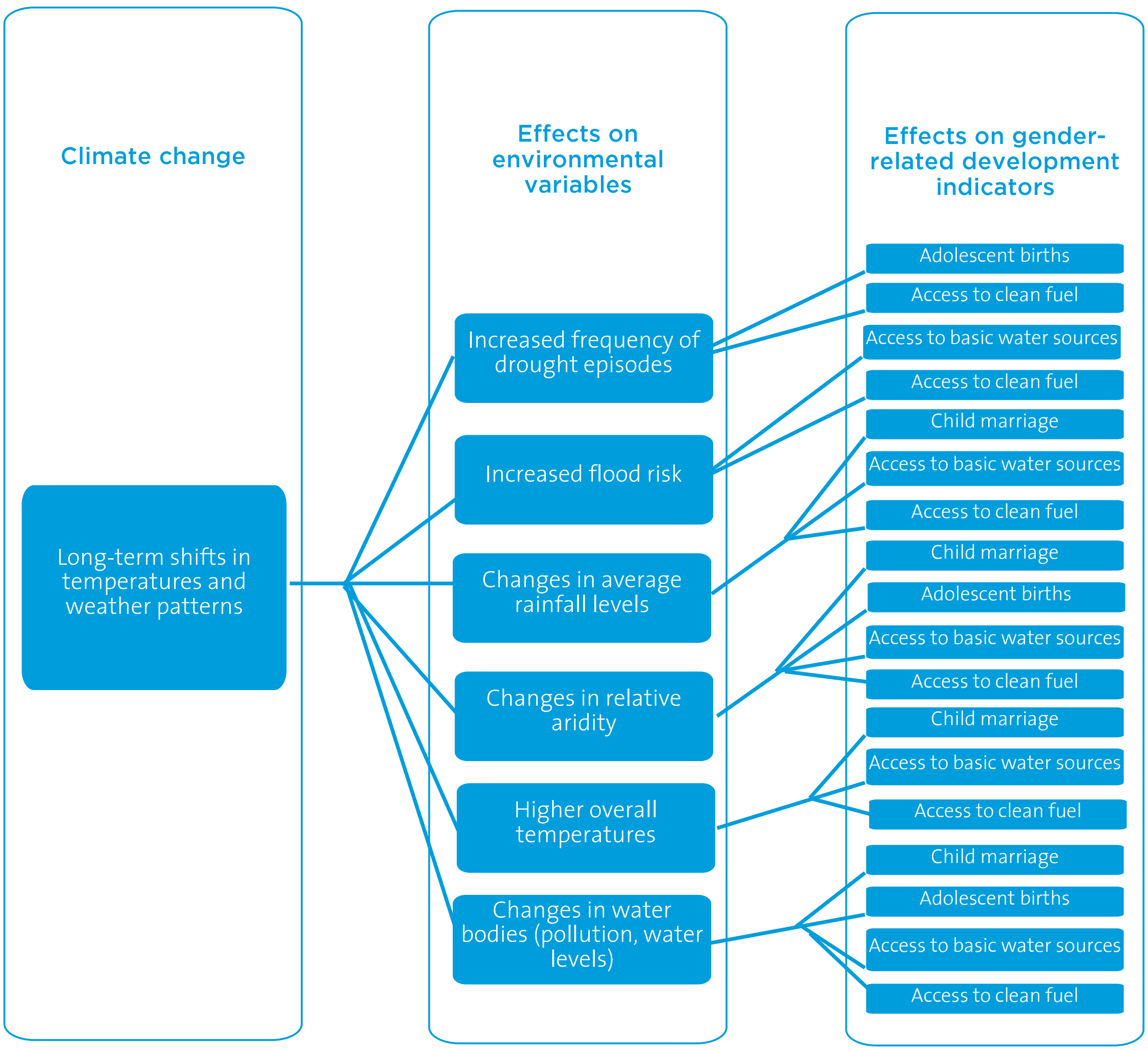
Overall, climate related variables have greater classification power for the risks of child marriage and the lack of access to basic drinking water sources and clean fuel, compared to risks of experiencing adolescent births or IPV

[37] K. Kirasich, et al. (2018). Random Forest vs Logistic Regression: Binary Classification for Heterogeneous Datasets. Available from: https://scholar.smu.edu/cgi/viewcontent.cgi?article=1041&context=datasciencereview
[38] Ashok Chilakapati (2019). Logistic Regression as a Nonlinear Classifier. *Towards data science*. See: https://towardsdatascience.com/logistic-regression-as-a-nonlinear-classifier-bdc6746db734.
[39] Distribution across countries where the value of "Flood risk 50" is 0: 96 per cent in Timor-Leste; 79 per cent in the Philippines; 66 per cent in Nepal; 36 per cent in Cambodia; and 21 per cent in Bangladesh.
[40] Although a correlation matrix was plotted to check for multicollinearity, the decision to drop variables from the model was guided by the variance inflation factor (VIF) – a measure of the amount of multicollinearity in a set of variables included in a regression model. Where VIF values were under the set threshold, they were not dropped from the model. While there is support for this practice in the literature, it is still possible that these highly correlated variables result in inflated standard errors, showing insignificant associations when they should be significant.

(figure 2). For the latter, in particular, the explanatory power of climate related variables was much lower, although not negligible.

Random forest analysis also showed that, among the countries considered, Bangladesh is where climate related variables have the most power in determining the risk of poorer outcomes on gender indicators.

FIGURE 2: Key findings from random forest (highest explanatory power variables only)



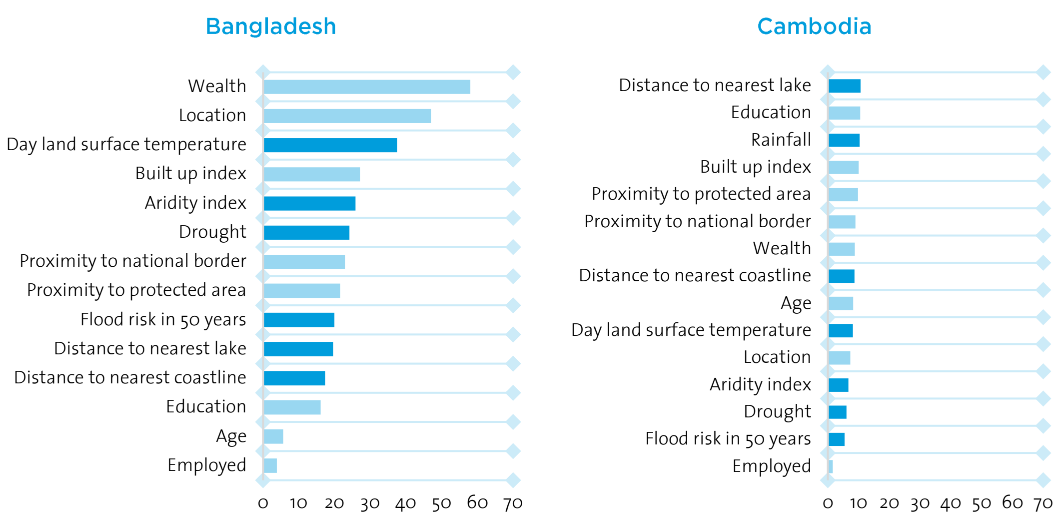
Note: The diagram only depicts gender related outcomes where removal of the environment variable resulted in a model decrease in accuracy (MDA) larger than 15 per cent in at least one country. It leaves out other associations that may be relevant but slightly weaker, for ease of representation. Refer to the description below for further detail.

Child marriage

Environmental variables play a major role in explaining the risk of child marriage (figure 3), particularly in countries where the practice is more culturally accepted. For instance, in all countries, proximity to water (lakes or coastline depending on the country) is among the top five most important variables for classifying women into high or low risk groups for experiencing child marriage. Living near water can have both positive and detrimental effects on poverty and livelihoods and consequently on child marriage (e.g. girls may be married off as a coping mechanism). For instance, sea level rise (and soil salinization) may be detrimental to the livelihoods of populations living near coastlines, but proximity to coasts may be advantageous for those engaged in fishery-related livelihoods. Random forest does not explain the direction of these associations but identifies the variable as powerful in predicting child marriage outcomes. Understanding in which cases proximity to water may be beneficial or detrimental to child marriage remains an area for further research.

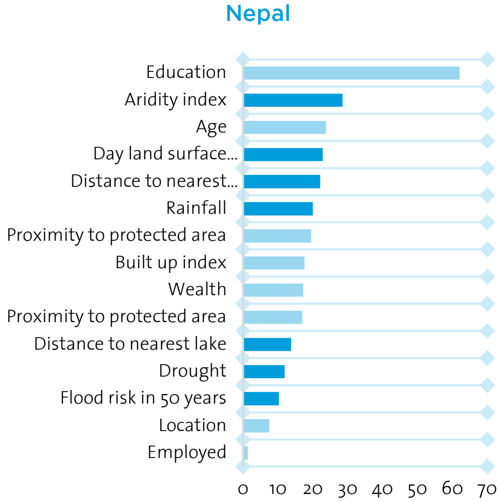
Relative aridity is also highly relevant to assess the risk of child marriage in Bangladesh (figure 4), Nepal and the Philippines, likely due to its effects on ecosystem productivity, and therefore agricultural yield, food security and other indicators related to poverty. Strongly connected with relative aridity, rainfall also appears important, particularly in Nepal, reinforcing this finding. Further details on how aridity and rainfall may affect child marriage, including the direction and strength of these associations, are explored in section 5.2.

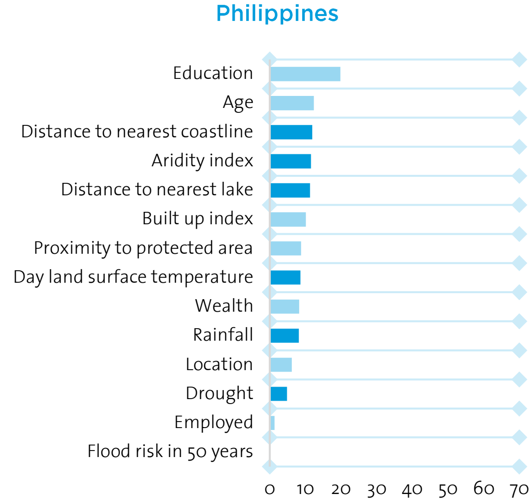
FIGURE 3: Mean decrease in accuracy (in event of variable removal) for child marriage rates, by country, percentage

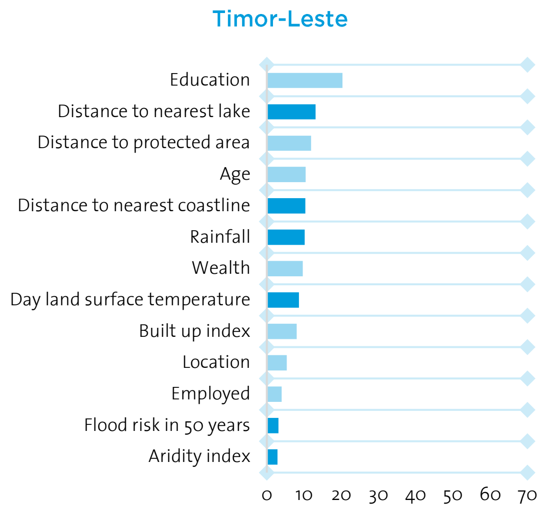


Note: Environment-related variables are shown in darker shade of blue for ease of interpretation.

FIGURE 3 (continued.): Mean decrease in accuracy (in event of variable removal) for child marriage rates, by country, percentage

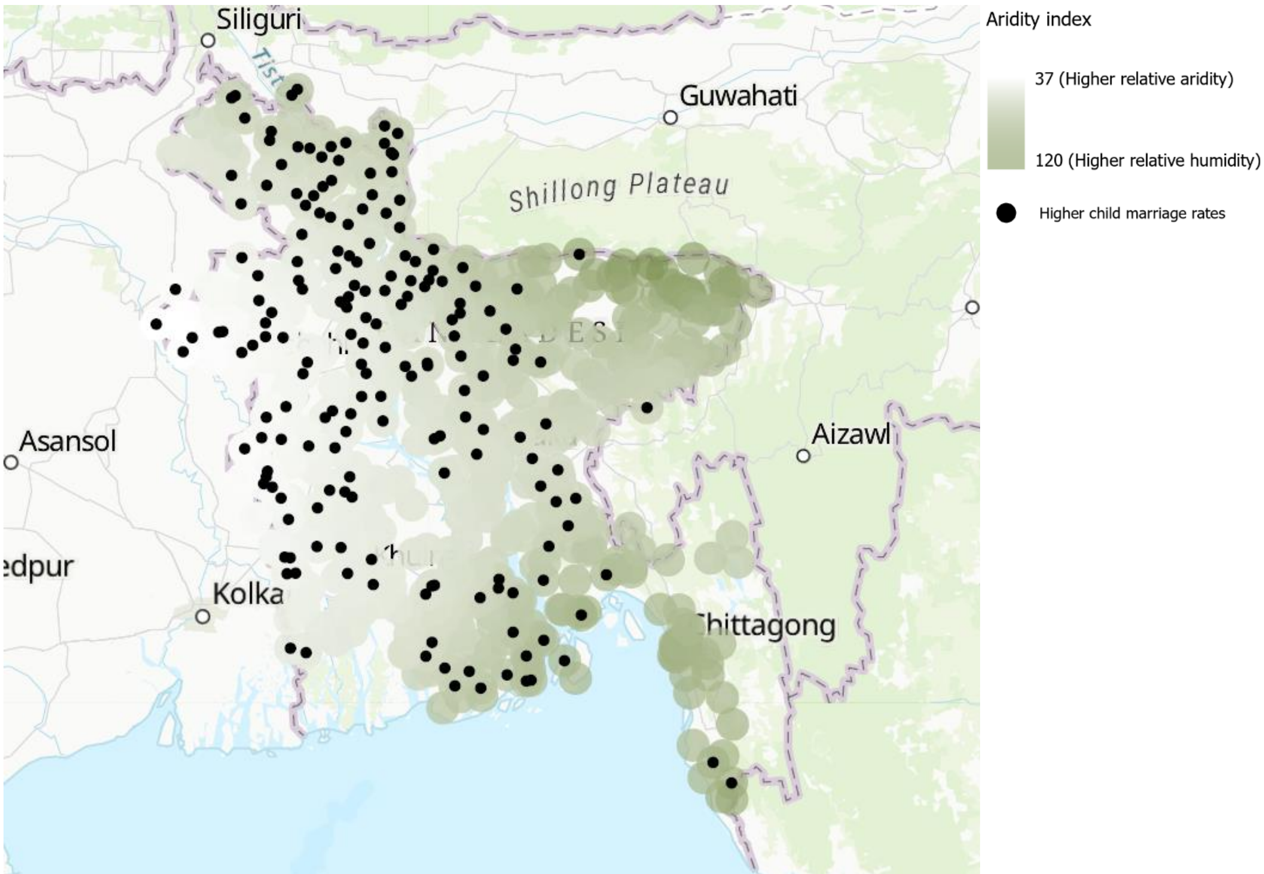






Note: Environment-related variables are shown in darker shade of blue for ease of interpretation.

FIGURE 4: Geographical distribution of clusters with high child marriage rates among women, by level of relative aridity, Bangladesh



Key for interpretation: The black markers represent clusters with high child marriage rates (top 25 per cent of cluster values).

Adolescent births

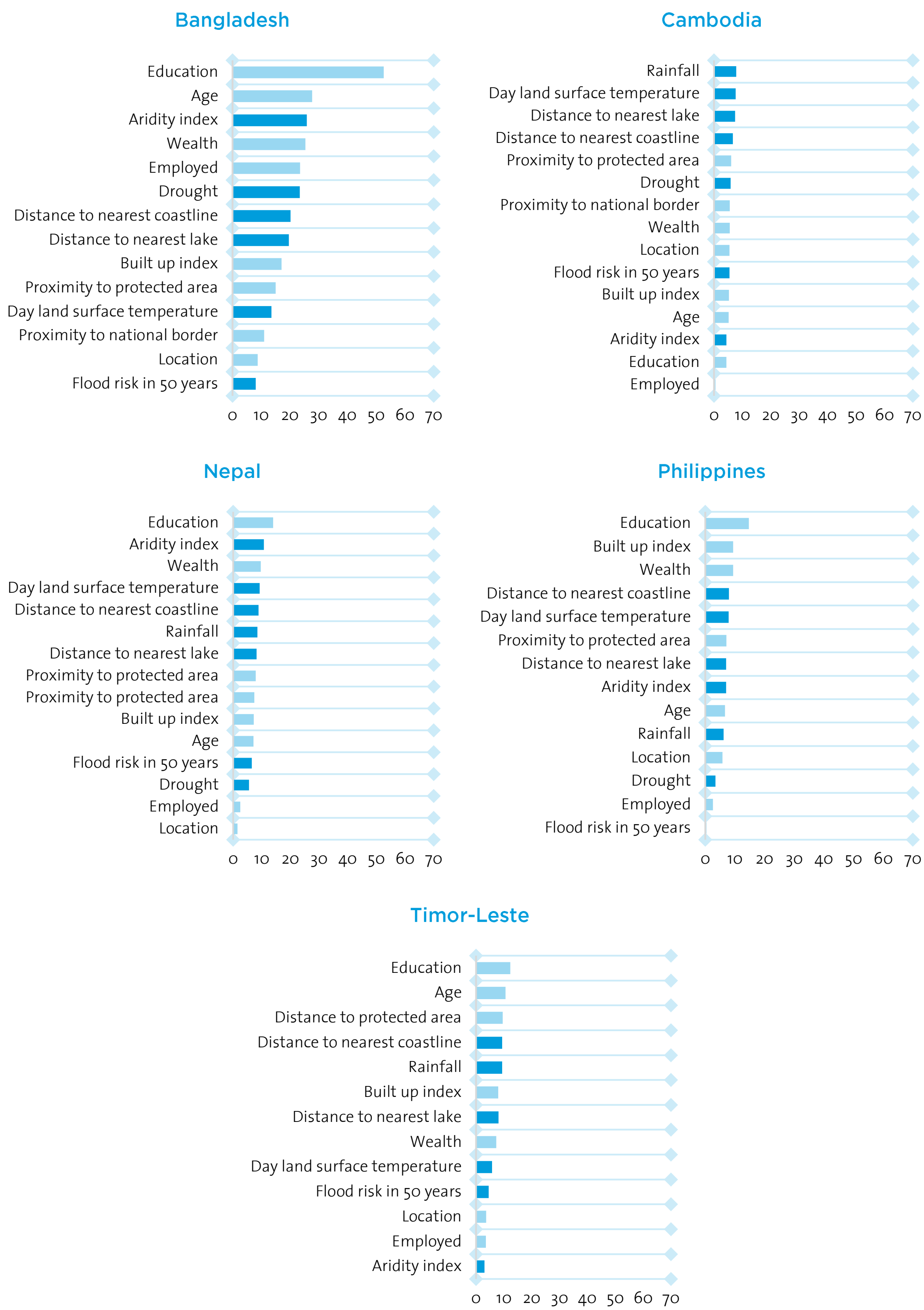
The prediction accuracy of adolescent birth models decreases when environmental variables are removed, but less so than in other models. Factors such as culture, religion, limited access to family planning and poor provision of reproductive health services are all known to contribute to adolescent births.[41] At the time of the analysis, data to control for these variables were not available, and these interactions may explain the weaker classification power of climate variables on adolescent births.

Child marriage rates are highly associated with adolescent birth rates, as early marriages often result in early pregnancies. It is therefore no surprise that, in line with findings pertaining to child marriage, distance to water (nearest lake or coastline) is also important to determine the risk of adolescent births; as is relative aridity in

[41] I. Yakubu and W.J. Salisu (2018). Determinants of adolescent pregnancy in sub-Saharan Africa: a systematic review. *Reproductive Health* See: https://reproductive-health-journal.biomedcentral.com/articles/10.1186/s12978-018-0460-4

Bangladesh and Nepal, where social norms enable child marriage practices and climate change may be amplifying the effects.

FIGURE 5: Mean decrease in accuracy (in event of variable removal) for adolescent birth rates, by country, percentage



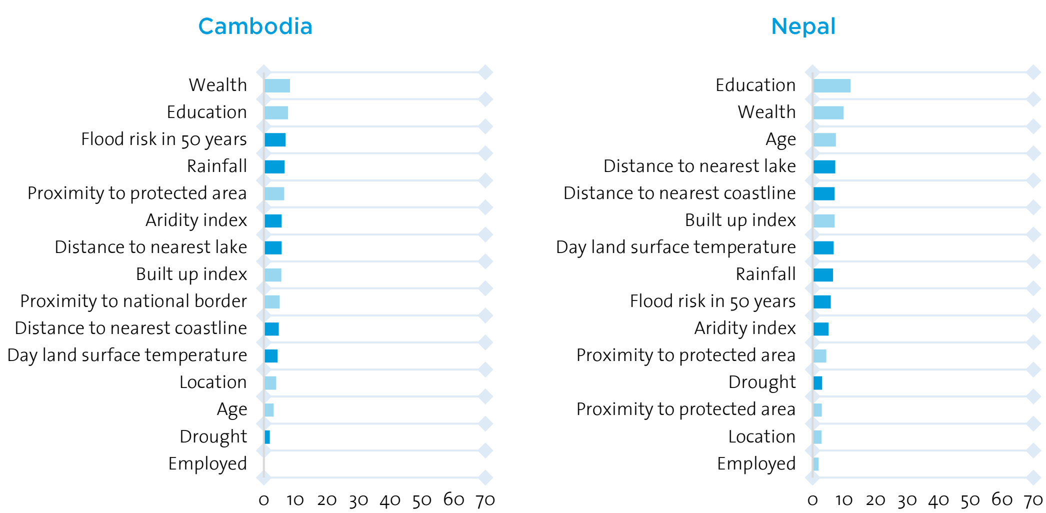
Note: Environment-related variables are shown in darker shade of blue for ease of interpretation.

Intimate partner violence

Random forest models show that, of all five gender outcomes considered, climate change variables have the poorest classification power for IPV in the past 12 months. In other words, after removing the climate variables from the IPV model, its accuracy drops by a small margin. This points to the possibility that IPV may also be driven by factors not considered in the study.

Among the factors related to climate change that were considered, average annual rainfall is relevant across countries (Cambodia, the Philippines and Timor-Leste), with model accuracy dropping by 7 per cent in Cambodia and 11 per cent in the Philippines and Timor-Leste if the variable is removed. The model also highlighted the importance of proximity to lakes, coastlines and protected areas, with mild effects across countries. Existing literature indicates that the drivers of IPV are multidimensional and highly localized,[42] with social norms playing a significant role. As such, although rainfall and proximity to water and protected areas may contribute to healthy natural resources, decreased economic stresses and, thus, reduced IPV, the reasons behind these associations are difficult to establish. Further research, including controlling for other known drivers of IPV, could help to better understand these associations.

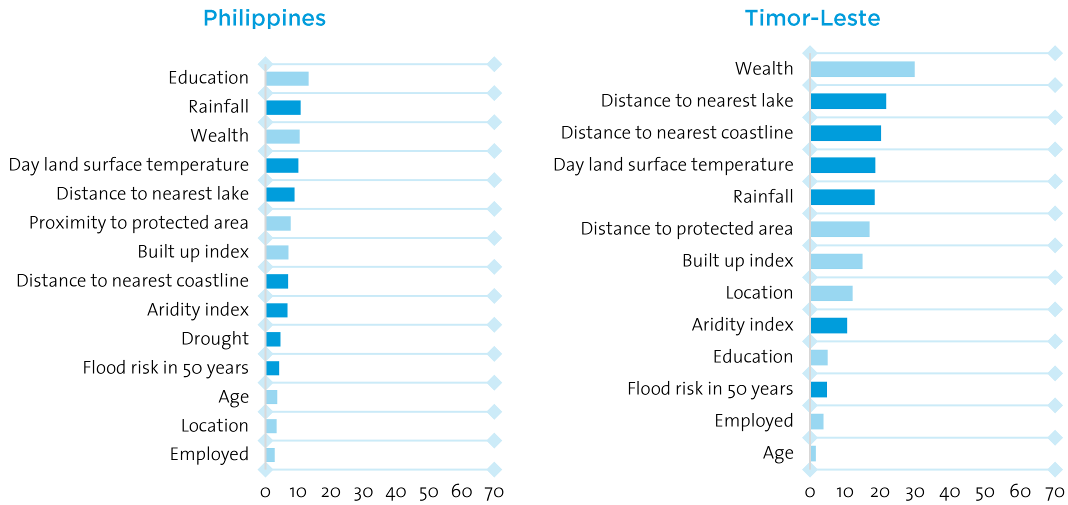
FIGURE 6: Mean decrease in accuracy (in event of variable removal) for intimate partner violence in the past 12 months, by country, percentage



Note: Environment-related variables are shown in darker shade of blue for ease of interpretation. Data for Bangladesh were not available at the time of this study.

[42] K.J. McCarthy, R. Mehta and N.A. Haberland (2018). Gender, power, and violence: A systematic review of measures and their association with male perpetration of IPV. *PLOS ONE.* Available from: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0207091.

FIGURE 6 (continued): Mean decrease in accuracy (in event of variable removal) for intimate partner violence in the past 12 months, by country, percentage



Note: Environment-related variables are shown in darker shade of blue for ease of interpretation. Data for Bangladesh were not available at the time of this study.

Access to basic drinking water sources

Climate related variables are powerful in classifying the risk of lacking access to basic water sources. Unlike other gender related outcomes, where education, age and wealth hold some of the highest classification power, climate related variables such as distance to lakes and coastlines, flood risk and temperatures have the highest power in predicting access to basic water sources.

The distance to the nearest lake matters greatly in all countries considered. Although living near a lake can facilitate access to livelihoods and infrastructure, it may also worsen exposure to water contamination. Geographical areas with surface water, such as lakes and streams, often have reservoirs of groundwater and other forms of subsurface water, which can be used as improved drinking water sources. Water exchanges between subsurface water and surface water take place regularly. Climate change is putting the quality and availability of freshwater sources at risk. Accelerated by rising temperatures and the use of pesticides and pollution, cyanobacterial blooms in lakes have increasingly become a challenge as they can impair the safety of drinking water and the effectiveness of water treatment plants[43]. If cyanobacteria reach wetlands and groundwater reservoirs near lakes, they may further affect the quality of the water in nearby areas.[44] Oxygen depletion in freshwater lakes, sedimentation, growth of aquatic weeds, changes in water levels and shifts in water species in lakes, all have accelerated in recent decades as well, with consequent effects on biodiversity loss and the quality of nearby drinking water.[45] Random forest shows that

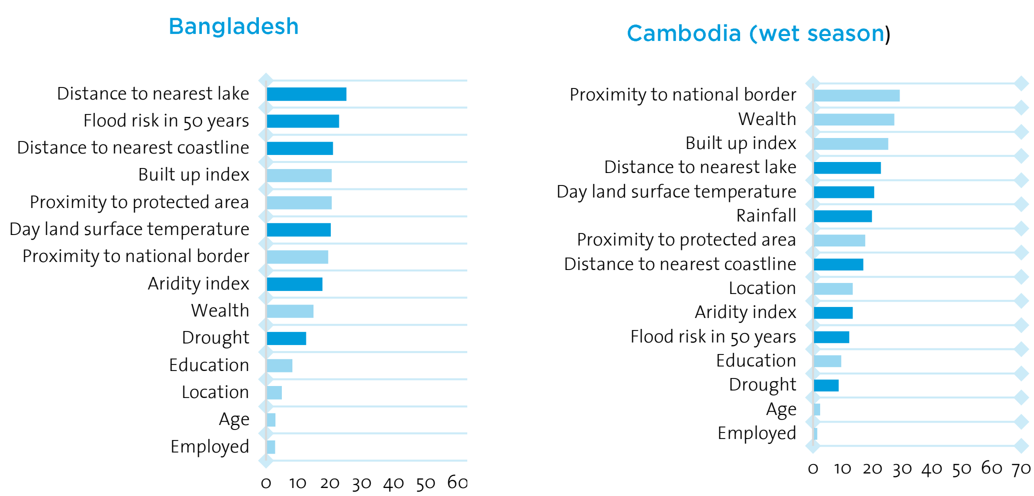
[43] National Geographic Society. Available from: https://www.nationalgeographic.org/encyclopedia/lake/
[44] S. Gkelis and A. Vlamis (2017). Can cyanobacteria infect underground water sources? Indications from small scale monitoring of a natural drinking water source. Available from: https://pagepressjournals.org/index.php/aiol/article/view/6280/6895.
[45] S.F. Jane, et al. (2021). Widespread deoxygenation of temperate lakes. Available from: www.nature.com/articles/s41586-021-03550-y.

living near lakes is important for determining the risk of lacking access to basic drinking water sources, but further analysis (section 5.2) will ascertain the direction of associations in each case.

Daytime land surface temperature also plays an important role, as expected, given its connections with forest transition and land degradation – both of which correlate with the quality of groundwater, aridification and extreme weather – which affect the availability of groundwater, rainwater and other improved water sources. This association is notorious across the five countries, especially the Philippines, where the accuracy of the model decreases by 31 per cent if the variable is removed. Logistic regression analysis and existing literature both confirm that this association is direct, that is, temperature rises are typically accompanied by phenomena that contribute to land degradation and worsen the quality of nearby drinking water sources (see section 5.2).

In Bangladesh, the probability of flooding is an important predictor for lacking access to basic drinking water sources. Given the cyclical nature of severe flooding in Bangladesh, it is well documented that sources are contaminated during floods when they are infiltrated by faecal matter and other debris.[46] To prevent waterborne diseases, population groups that typically rely on open surface water for drinking switch to bottled water and other improved sources during floods. A similar shift takes place in Cambodia, where 11 per cent of women shift away from drinking open surface water during rainy periods. Interestingly, in Cambodia, this association is only obvious when floods take place during the dry season, as during rainy seasons, many people are able to rely on rainwater (an improved source) for drinking.

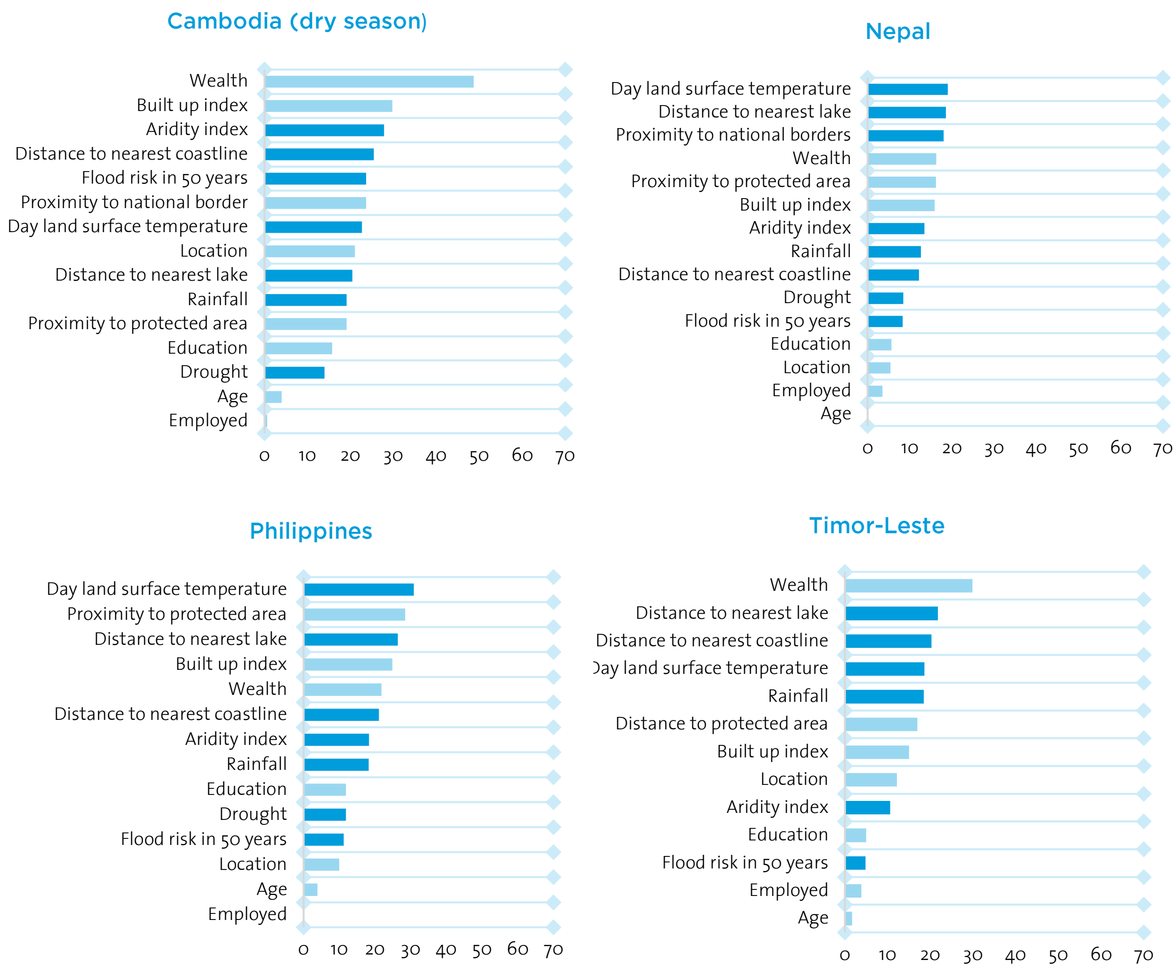
FIGURE 7: Mean decrease in accuracy (in event of variable removal) for lack of access to basic drinking water sources, by country, percentage



Note: Environment-related variables are shown in darker shade of blue for ease of interpretation.

[46] M.S. Islam, et al. (2007). Faecal contamination of drinking water sources of Dhaka city during the 2004 flood in Bangladesh and use of disinfectants for water treatment. *Journal of applied microbiology*. Available from: https://pubmed.ncbi.nlm.nih.gov/17584454/

FIGURE 7 (continued): Mean decrease in accuracy (in event of variable removal) for lack of access to basic drinking water sources, by country, percentage



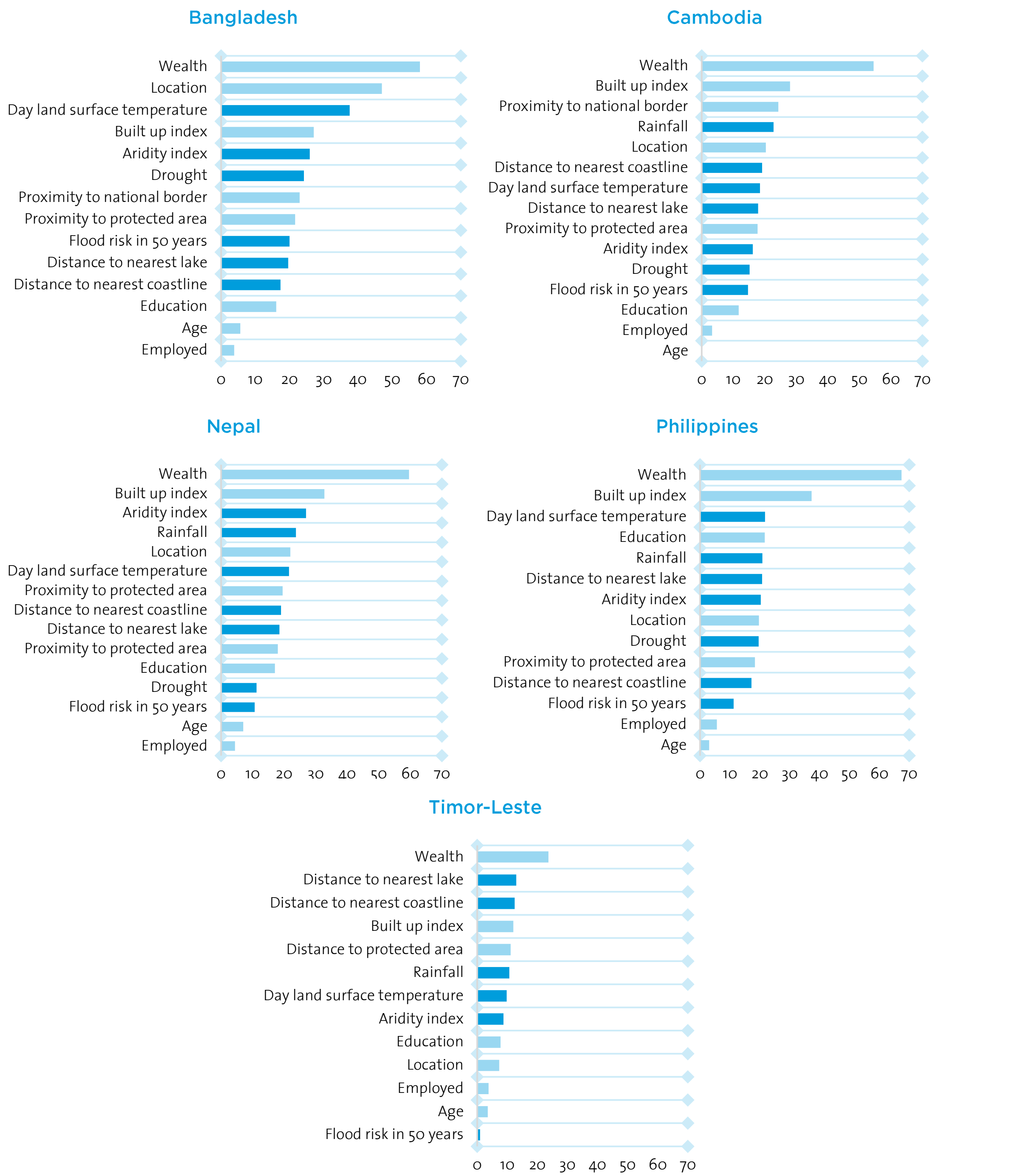
Note: Environment-related variables are shown in darker shade of blue for ease of interpretation.

Use of clean cooking fuel

Of all gender related outcomes considered for this analysis, climate related variables are best at classifying the risk of lacking access to clean cooking fuel. Average daytime land surface temperature, for instance, is of relevance across all countries considered (in Bangladesh model accuracy would decrease by as much as 38 per cent if the variable was removed, in Nepal and the Philippines accuracy would decrease by 22 per cent). Random forest analysis shows the high importance of this variable, but further analysis demonstrated that other variables not included in the model are also at play, such as fuel cost and infrastructure (section 5.2). Overall, warmer temperatures are accompanied by land degradation, deforestation, erratic precipitation patterns and reduced ecosystem production, which may lower the affordability of clean fuel (prompting people to shift to unclean fuel). However, fuel infrastructure and prices may alter and even reverse this association (see figures 21 and 22 in section 5.2).

Aridity index, rainfall and distance to water bodies are also relevant across countries. Previously noted relationships between these variables and ecosystem production – and therefore economic strains and affordability of fuel – may explain these connections. To gain important insights and fully understand the independent effect of climate related variables, this analysis could be repeated with fuel cost and infrastructure data.

FIGURE 8: Mean decrease in accuracy (in event of variable removal) for lack of access to clean fuel, by country, percentage

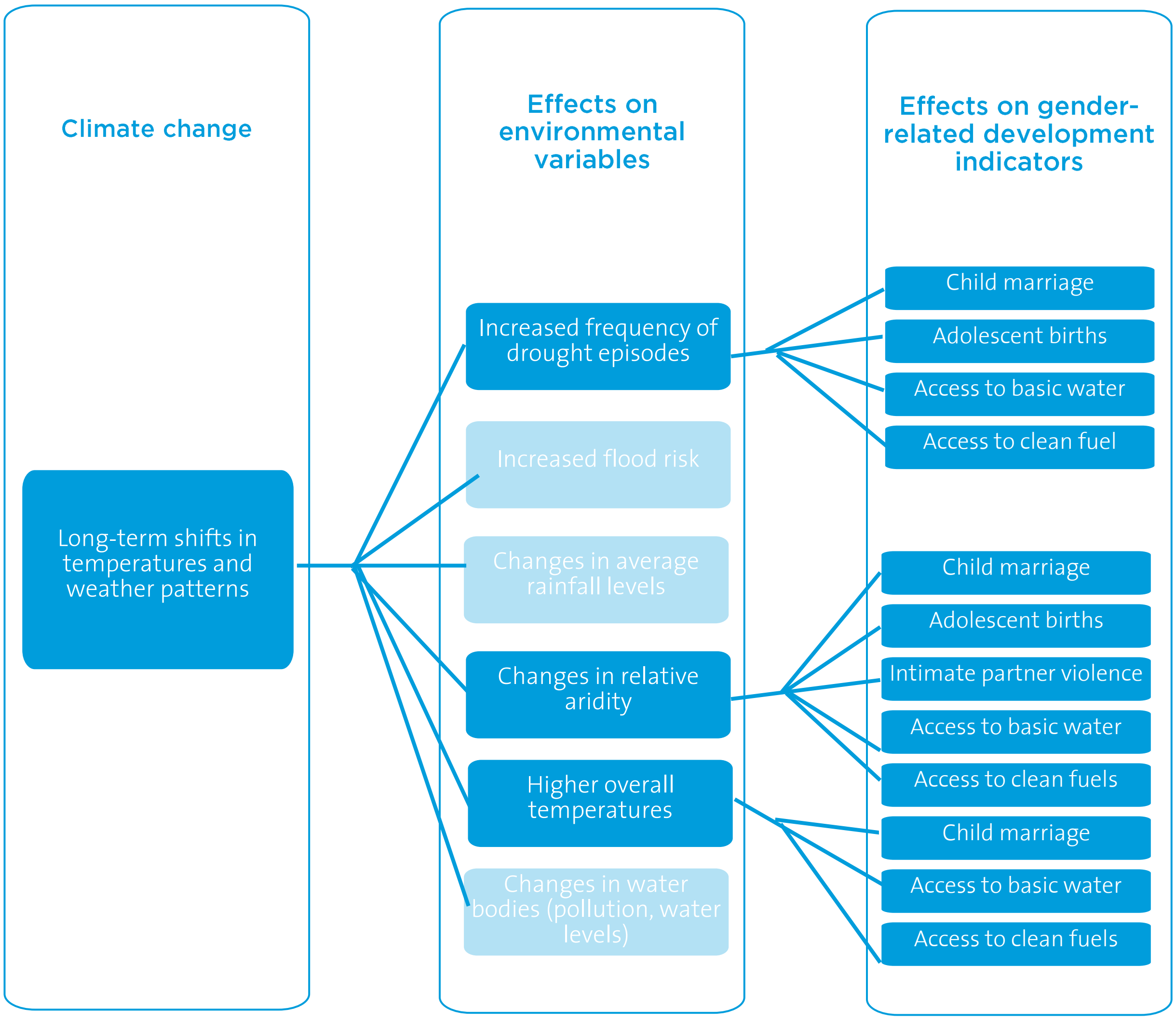


Note: Environment-related variables are shown in darker shade of blue for ease of interpretation.

5.2. Frequent drought episodes, increased relative aridity and rising temperatures are worsening gender outcomes across most countries

Logistic regression analysis shows that drought episodes, changes in relative aridity and increases in average daytime land surface temperatures significantly worsen **gender-related outcomes** across most countries. These findings support the hypothesis.

FIGURE 9: Key findings from logistic regression analysis (Most significant associations only, P value=0***)

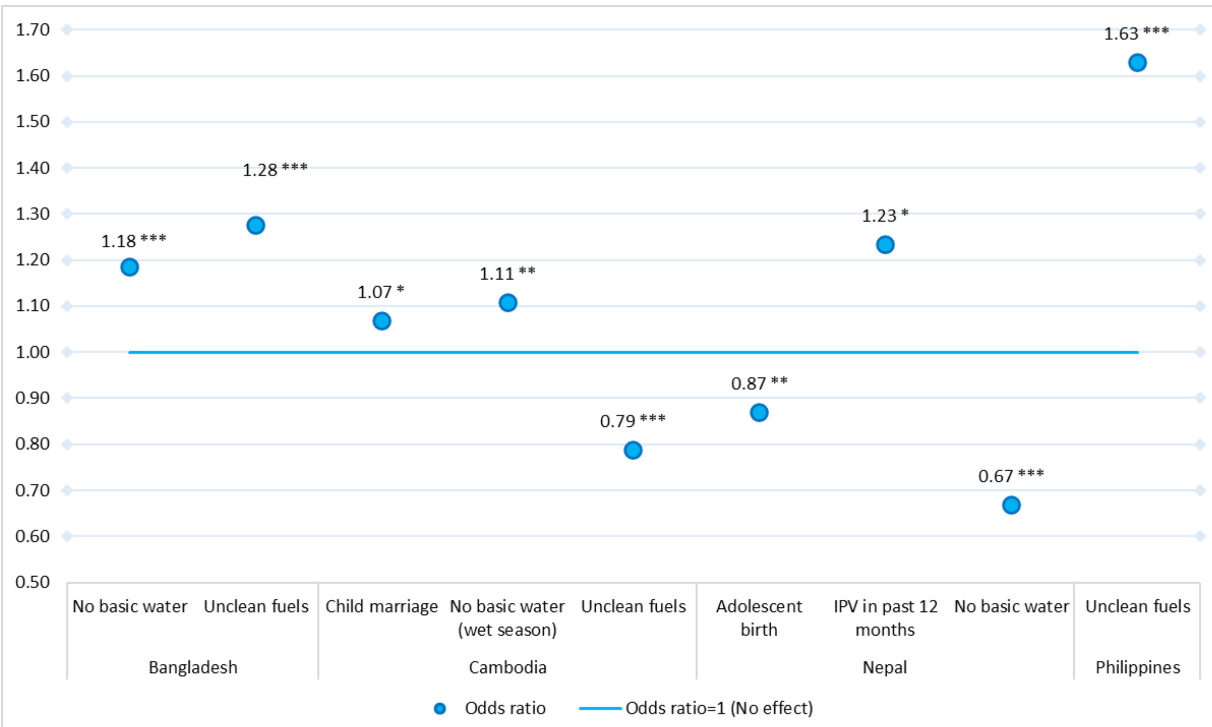


Note: The diagram depicts gender related outcomes that were found to be significantly associated with the climate change/environmental variables with strong levels of association (p value= 0, or ***) in at least one country. It leaves out other associations that may have been slightly weaker, regardless of the size of the effect (adjusted odds ratio). To better interpret the results, both the size of the effect and strength of the association must be considered.

Drought episodes

Drought episodes are largely associated with worsening gender outcomes (figure 10). The intensity of these associations varies across countries, as the impact of drought depends on multiple factors, including whether the region is arid or semi-arid, whether drought episodes are short-term or long-term, and whether the effects are localized or widespread.[47][48] Dependence on agriculture in each country may also determine the extent of these impacts.[49] As people's capacity to cope with droughts is impacted by their type of job, ownership of assets, access to credit, coverage of early warning systems, availability of infrastructure and many other factors, control variables are needed to isolate the effect of drought on gender related outcomes, but data for many of those factors were not available at the time of research, which may explain the reverse associations found in a few instances. The strongest associations for drought episodes, across countries, were found with access to basic drinking water sources and clean cooking fuel.

FIGURE 10: Adjusted odds ratios for the effect of drought episodes on gender related development indicators, by country



Note: Significance codes: 0 = *** ; 0.001 = ** ; 0.01 = *

Odds ratios that were insignificant have been omitted from the graph. Values greater than 1 indicate a higher likelihood of an increase or decrease in the indicator, given a one unit increase in climate change related factors, values lower than 1 indicate that an increase in climate change related factors would reduce the likelihood of changes in the indicator, and those equal to 1 indicate no effect. For Cambodia, data on access to water for both dry and wet seasons were considered, but the adjusted odds ratio is only significant for the wet season. Data for Timor-Leste on drought episodes were excluded from the analysis due to data quality concerns.

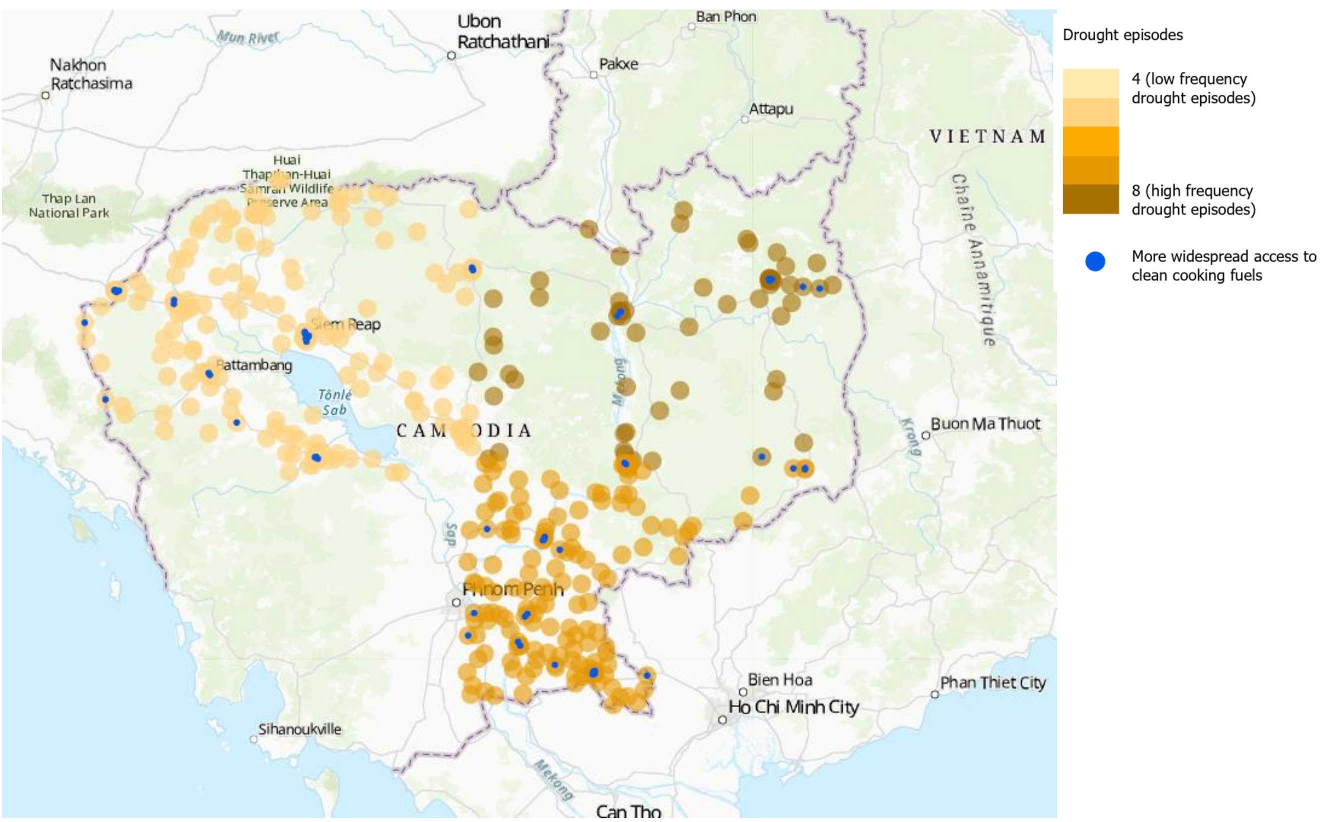
In places where droughts are frequent, women are more likely to encounter barriers to access basic water sources. The adjusted odds ratios (AORs) are significant in three of the four countries considered, Bangladesh, Nepal and Cambodia (wet season), and coefficients are larger relative to other indicators, suggesting a higher degree of effect. In Nepal the relationship appears inverse, with more frequent drought episodes correlated with higher likelihood

[47] S. Kulkarni and N. Rao (2008). "Gender and Drought in South Asia: Dominant Constructions and Alternate Propositions". In Jasveen Jairath and Vishwa Ballabh (eds). *Drought and Integrated Water Resource Management in South Asia*.
[48] While the drought episode variable included in the analysis does not give any information on the duration, nature of onset or coverage of drought, it represents the frequency of occurrence (from 1 to 10, with 1 meaning low frequency and 10 meaning high frequency).
[49] See www.fao.org/land-water/water/drought/droughtandag/en/.

of accessing basic water sources (AOR=0.67***), however, geospatial analysis reveals that drought-prone clusters are largely located in or near Kathmandu, where water provision infrastructure is better established. This demonstrates the importance of controlling for water infrastructure in future analyses.

In line with existing literature, this analysis finds frequent drought episodes are strongly associated with limited access to clean cooking fuel in Bangladesh and especially the Philippines, where the coefficients are some of the largest in this study (Bangladesh AOR 1.28***; Philippines AOR 1.63***). On the one hand, fuel cost may contribute to this association as water scarcity limits energy production by hydropower and coal plants, which are highly dependent on water for cooling, thus rising energy prices. On the other hand, drought-driven economic stresses from reduced ecosystem productivity may push households to rely on cheaper cooking fuels, such as wood, charcoal or kerosene. In Cambodia this relation appears inverse (AOR 0.79***), and it is likely influenced by provincial differences in electricity prices that reflect grid development, high-voltage transmission connections, hydropower dams, provincial tariffs and other factors.[50] Prices are cheaper in the Phnom Penh region, Rattanak Kiri and Svay Rieng[51]. As figure 11 shows, clean cooking fuel use is more prevalent in areas where drought episodes are more frequent.

FIGURE 11: Geographical distribution of clusters where women have more widespread access to clean cooking fuel, by frequency of drought episodes, Cambodia



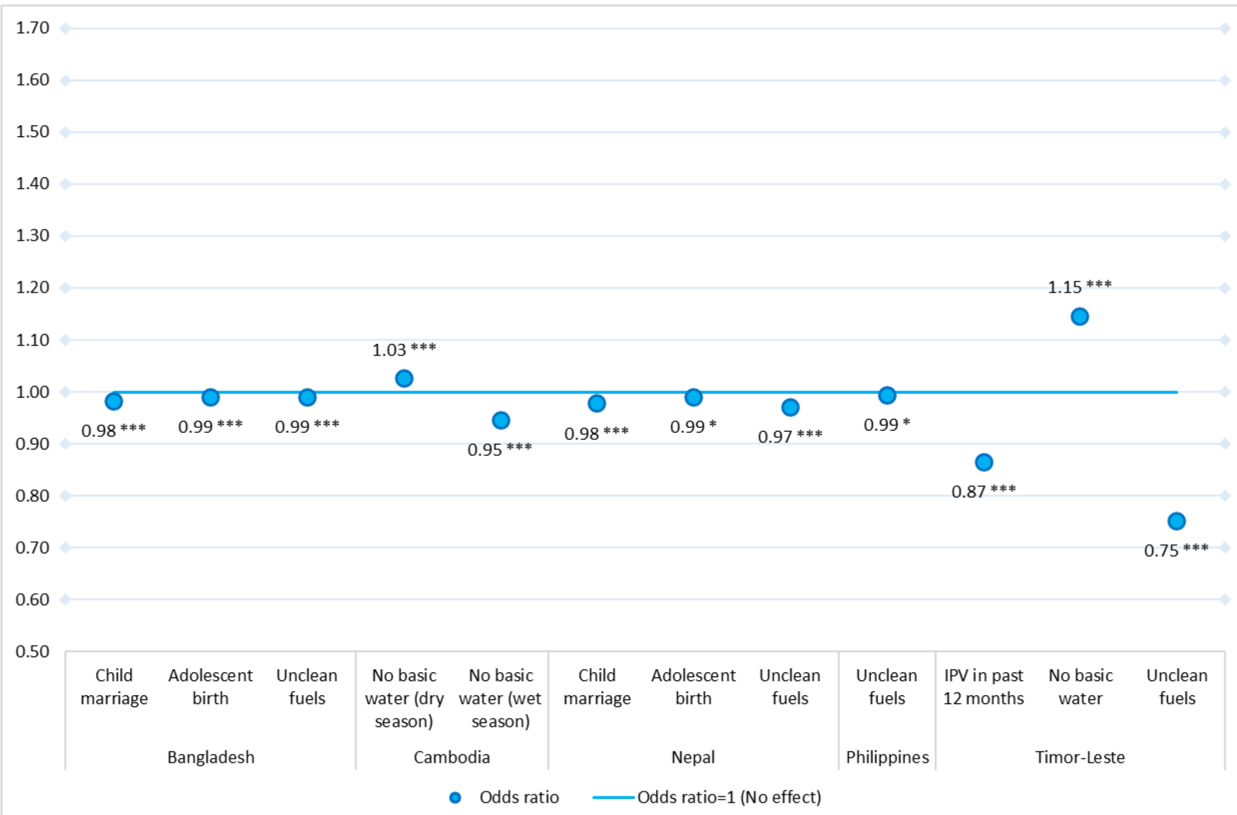
Key for interpretation: Blue dots represent clusters with higher use of clean fuel (bottom 25 per cent of cluster values for use of unclean fuel). **Note:** Clean fuels are depicted as the widespread use of unclean fuel makes it difficult to visually identify patterns.

[50] See www.eria.org/Chapter%207-Cambodia%27s%20Electricity%20Sector%20in%20the%20Context%20of%20Regional%20Electricity%20Market%20Integration.pdf.
[51] Council for Development of Cambodia https://cdc.gov.kh/

Relative aridity

Evidence indicates that higher relative aridity (as measured by lower values of the aridity index)[52] is mostly detrimental to gender related outcomes. While humid conditions are conducive to healthy aquifers and thriving vegetation and fauna, increasingly arid conditions are known to worsen agricultural yield and biodiversity loss, as well as to put pressure on the livelihoods of people highly dependent on these natural resources.[53] Despite the significant associations between relative aridity and gender related outcomes, the effects are relatively small compared to other climate variables across countries, with the exception of Timor-Leste for the prevalence of IPV, access to basic water sources and the use of clean cooking fuel.

FIGURE 12: Adjusted odds ratio for the effect of aridity index on gender related development indicators, by country



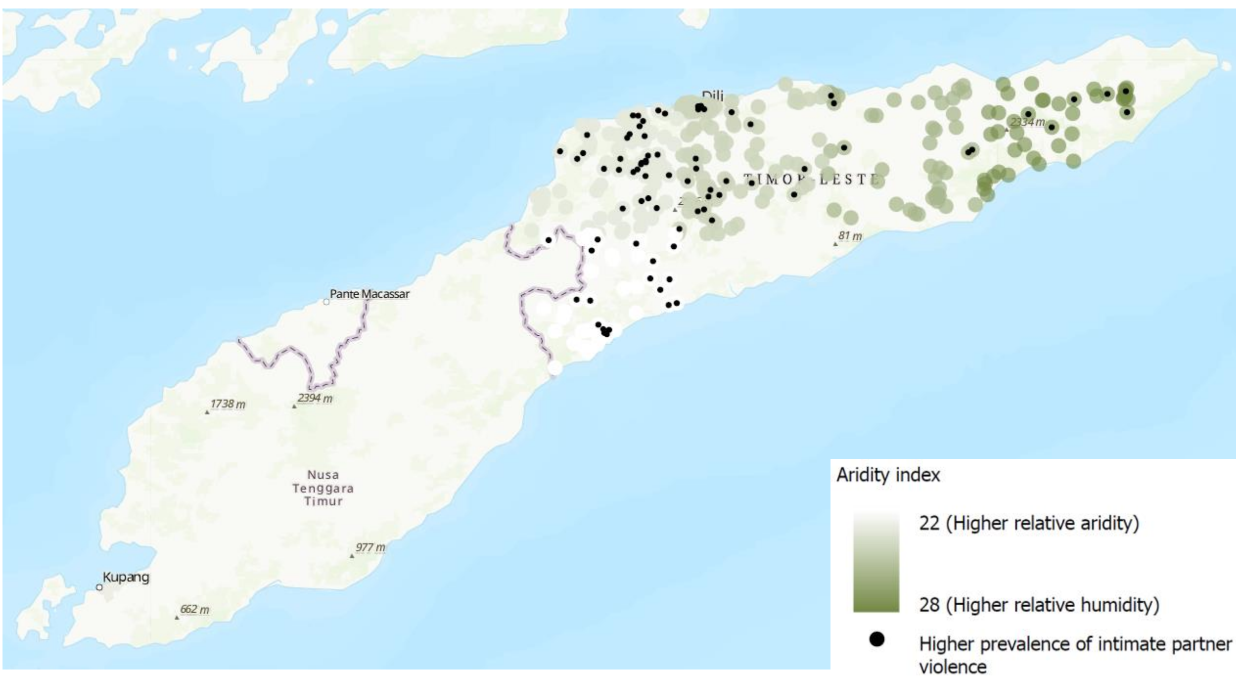
Note: Odds ratios that were insignificant have been omitted from the graph. (Significance codes: 0 = *** ; 0.001 = ** ; 0.01 = *)

[52] A high aridity index indicates either high rainfall, little evaporation, or both (thus, humid conditions). Relative aridity differs from droughts. The drought episodes variable only takes precipitation into consideration, while aridity index also measures evapotranspiration, and thus provides a better measure for the annual environment, as opposed to anomalous weather events.

[53] Note that arid conditions do not necessarily mean lack of precipitation. Rather, high relative aridity appears correlated with erratic weather patterns, including flooding. See www.researchgate.net/publication/224962450_Climate_change_flooding_in_arid_environments_and_erosion_rates.

In Timor-Leste, increases in relative aridity correlate with rises in IPV (figure 13). With a prolonged history of conflict and widespread poverty, approximately 35 per cent of women in Timor-Leste experienced physical and/or sexual violence at the hands of their partner in a 12-month period. Literature indicates that stress associated with bride price, a phenomenon closely linked to poverty, may also contribute to the high prevalence IPV.[54,55] It is possible that the economic stresses of aridity may be worsening poverty, increasing pressures for meeting bride price commitments and overall worsening IPV. The projected effects of climate change in Timor-Leste (temperatures are expected to increase by 0.3°C–1.2°C by 2030, which will alter rainfall patterns and relative aridity) and its heavy dependence on agriculture (it is the main source of income for more than 80 per cent of the population)[56] may worsen the risk of IPV in the future.

FIGURE 13: Geographical distribution of clusters with high rates of intimate partner violence in the past 12 months, by level of relative aridity, Timor-Leste



Key for interpretation: The black markers represent clusters with higher prevalence of intimate partner violence (top 25 per cent of cluster values).

Similarly, aridification correlates with steeper barriers to cooking with clean fuel (figure 12). Contributing factors may include affordability and availability of clean fuel sources, and the former is influenced by aridity in particular

[54] S. Rees, et al. (2017). Associations between bride price stress and intimate partner violence amongst pregnant women in Timor-Leste. *Global Health*. Available from: https://globalizationandhealth.biomedcentral.com/articles/10.1186/s12992-017-0291-z#citeas.

[55] Bride price in Timor-Leste involves an obligation on the husband to provide for all traditional events, including funerals and weddings, as well as ongoing support to the bride's family as a form of marriage expense.

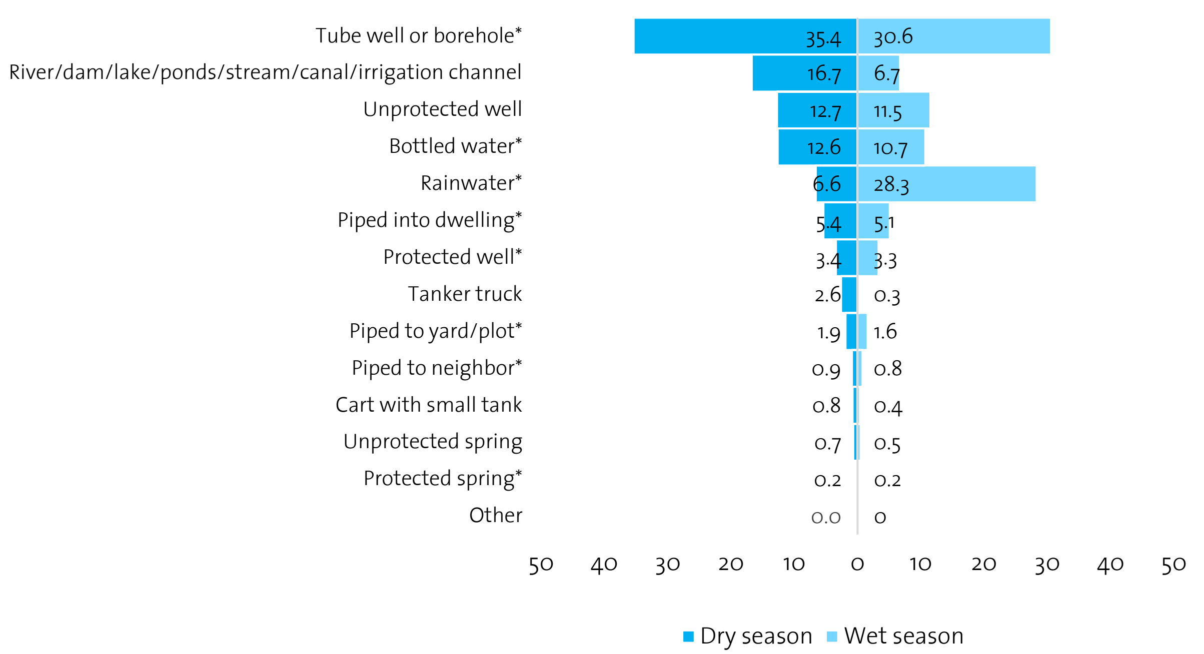
[56] See: www.greenclimate.fund/sites/default/files/document/timor-leste-country-programme.pdf.

(rainfall contributes to curbing electricity prices and maintaining livelihoods). Fuel prices may also play a key role, but data by type and location were not available at the time of analysis.

More humid areas of Timor-Leste see bigger challenges accessing basic drinking water sources (AOR=1.15***). This aligns with the findings on drought episodes, and with literature about increasing rainfall affects water supply treatment and heightening waterborne and other diseases[57], as well as with associations reflected in other countries, such as in Cambodia during the dry season.

Seasonal data can reveal nuances in the effects of precipitation and relative aridity on clean water access. In Cambodia, seasonal data show increases in humidity worsen access to basic water sources during the dry season but improve it during the wet season (AOR=1.03*** during the dry season, AOR=0.95*** during the wet season). This is largely due to differences in usage of water sources in humid compared to arid environments across seasons (figures 14 and 15). Many women in humid clusters, where rainwater is abundant, rely on rainfall (an improved source) during the wet season but shift to unprotected wells and open surface water during dry seasons when rain is unavailable. In arid clusters, however, tube wells (an improved source) are more commonly available throughout the year, since rainwater is not as dependable. This highlights risks heightened by climate change: shifts in relative humidity are likely to further reduce the predictability of water availability, affect water quality and increase related burdens on women.

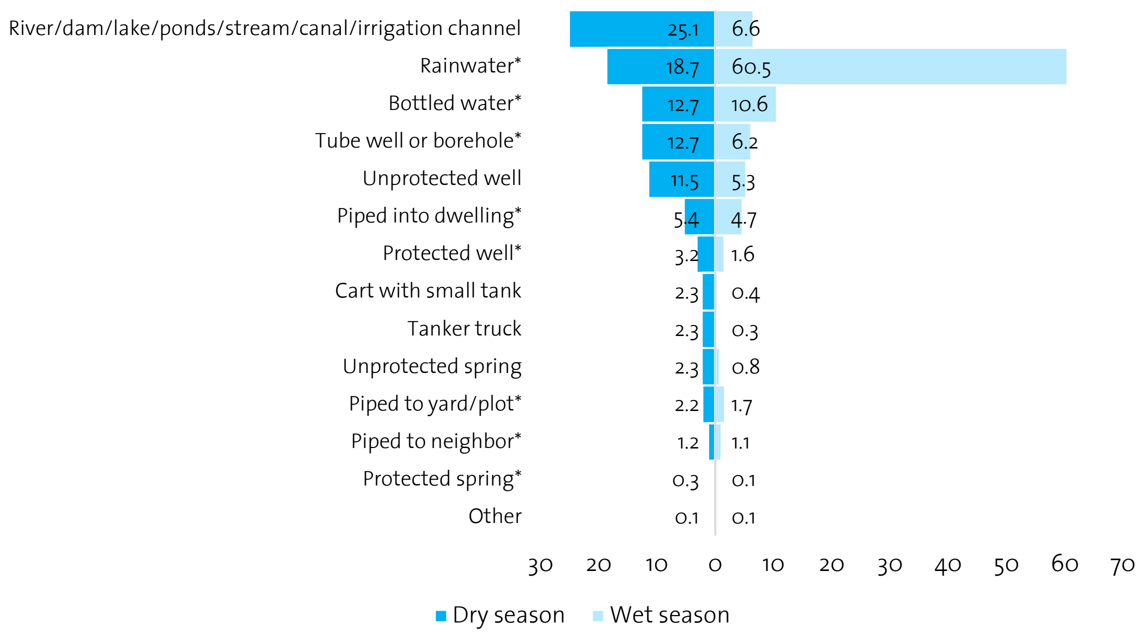
FIGURE 14: Main source of drinking water among women living in arid areas, Cambodia, dry and wet season (Percentage)



Note: An asterisk "*" indicates improved water source. Clusters are classified as arid if aridity index values fall in the bottom 25 per cent of all values.

[57] Ibid.

FIGURE 15: Main source of drinking water among women living in humid areas, Cambodia, dry and wet season (percentage)

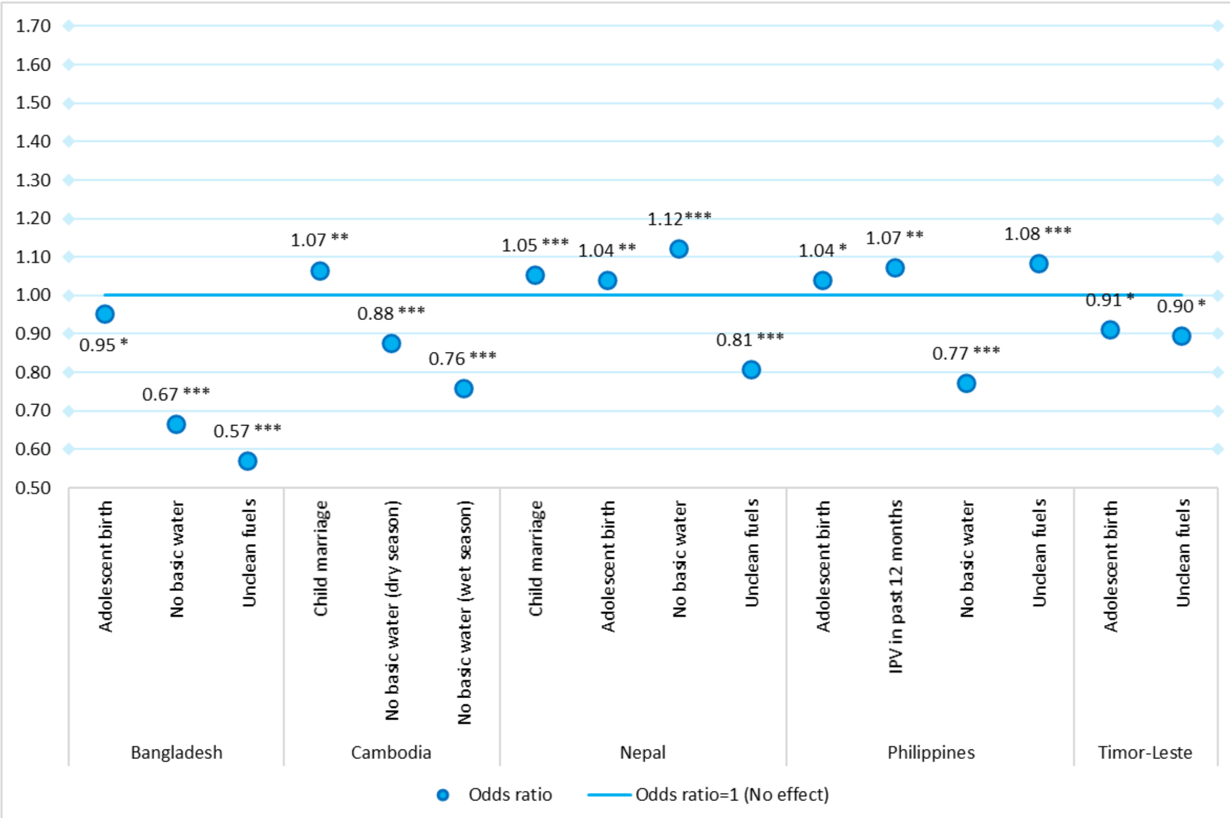


Note: An asterisk "*" indicates improved water source. Clusters are classified as humid if aridity index values fall in the top 25 per cent of all values.

Daytime land surface temperature

Temperatures are strongly connected with gender related outcomes across almost every country included in this analysis, and the effects are generally large (figure 16).

FIGURE 16: Adjusted odds ratios for the effect of day land surface temperature on gender related development indicators, By country



Note: Odds ratios that were insignificant have been omitted from the graph. (Significance code: 0 = *** ; 0.001 = ** ; 0.01 = *)

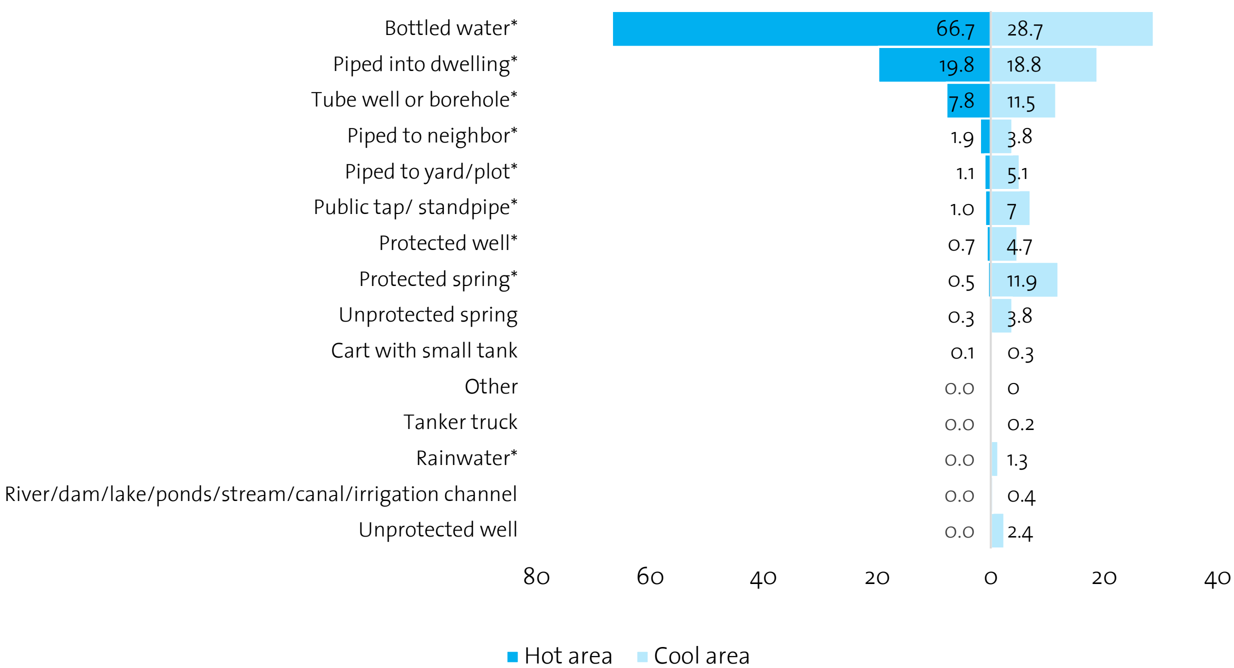
In Cambodia and Nepal, increases in daytime land surface temperature enhance the odds of child marriage significantly. This is likely linked to the effect of temperature on ecosystem productivity, which contributes to economic insecurity and the use of child marriage as a coping strategy.[58] In Nepal, this association is stronger (AOR=1.05***), and high child marriage rates are heavily concentrated across warm clusters in the south-eastern Terai region, where prevailing social norms and traditions are supportive of child marriage practices.[59] Because the regression analysis included controls for wealth and location, two known predictors for child marriage, the findings indicate that temperature rises may exacerbate these behaviours where the practice already existed, and high child marriage rates are not driven by poverty alone.

In Bangladesh, Cambodia and the Philippines, increases in temperatures correlate with better access to basic drinking water sources. Additional analysis is necessary to ascertain the reasons, but the effects of temperatures on

[58] L. Rumble et al. (2018). An empirical exploration of female child marriage determinants in Indonesia. *BMC Public Health*. Available from: https://bmcpublichealth.biomedcentral.com/articles/10.1186/s12889-018-5313-0; and World Bank and ICRW (2016). Knowledge Brief: Basic profile of child marriage in Nepal. Available from: https://openknowledge.worldbank.org/bitstream/handle/10986/24546/BasicoprofileoofochildomarriageoinoNepal.pdf?sequence=1&isAllowed=y.
[59] S. Amin and A. Bajracharya (2011). Costs of marriage—Marriage transactions in the developing world. Available from: https://knowledgecommons.popcouncil.org/departments_sbsr-pgy/833/.

freshwater availability and contamination could be contributing to these associations. Temperature rises typically occur simultaneously with fresh water source depletion (e.g. wetland exhaustion or transition) and land degradation (e.g. dry forest clearing, salinization)[60], which may result in poor rain absorption and thus runoff draining into waterways.[61] Consequently, populations living in high temperature clusters may shift drinking water sources from open water to improved sources such as bottled water or rainwater. In the Philippines, for instance, women living in hot clusters depend on bottled water disproportionately (66.7 per cent, compared to 28.7 in cooler clusters); in Cambodia they depend largely on rainwater (51.1 per cent, compared to 29.5 in cooler clusters) during the rainy season.

FIGURE 17: Main source of drinking water among women living in hot and cool areas, Philippines, (Percentage)



Note: An asterisk "*" indicates improved water source. Clusters are classified as hot if daytime land surface temperatures fall in the top 25 per cent of all values and cool if daytime land surface temperatures fall in the bottom 25 per cent of all values.

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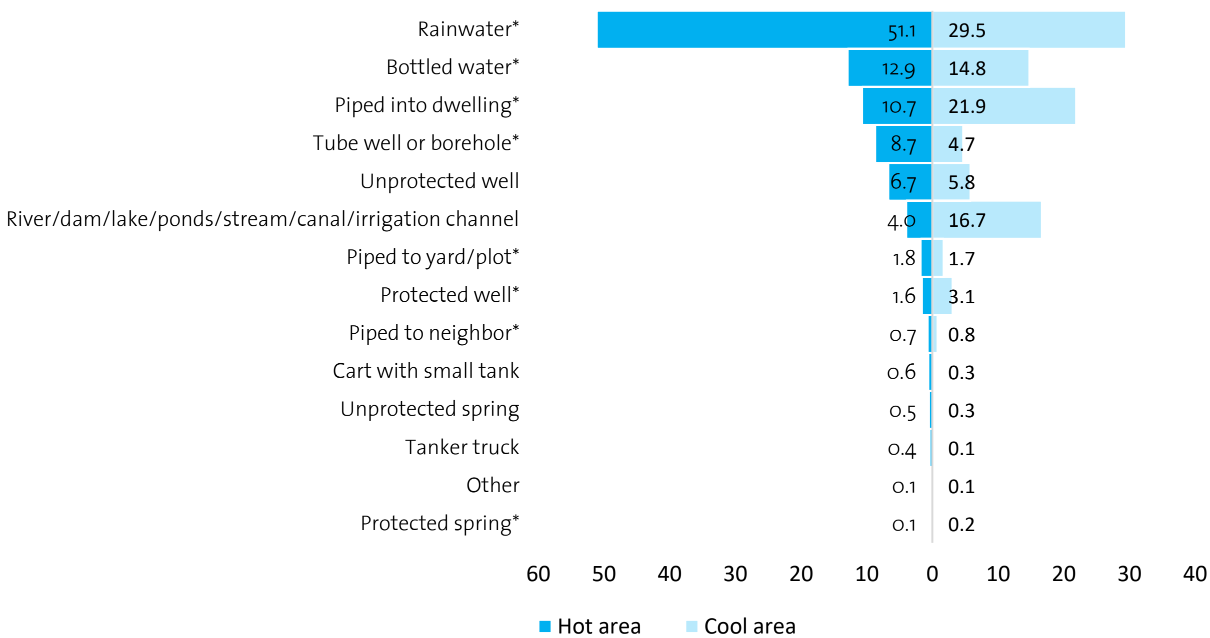
[60] See www.ipcc.ch/srccl/chapter/chapter-4/.
[61] See www.nationalgeographic.org/article/how-climate-change-impacts-water-access/.

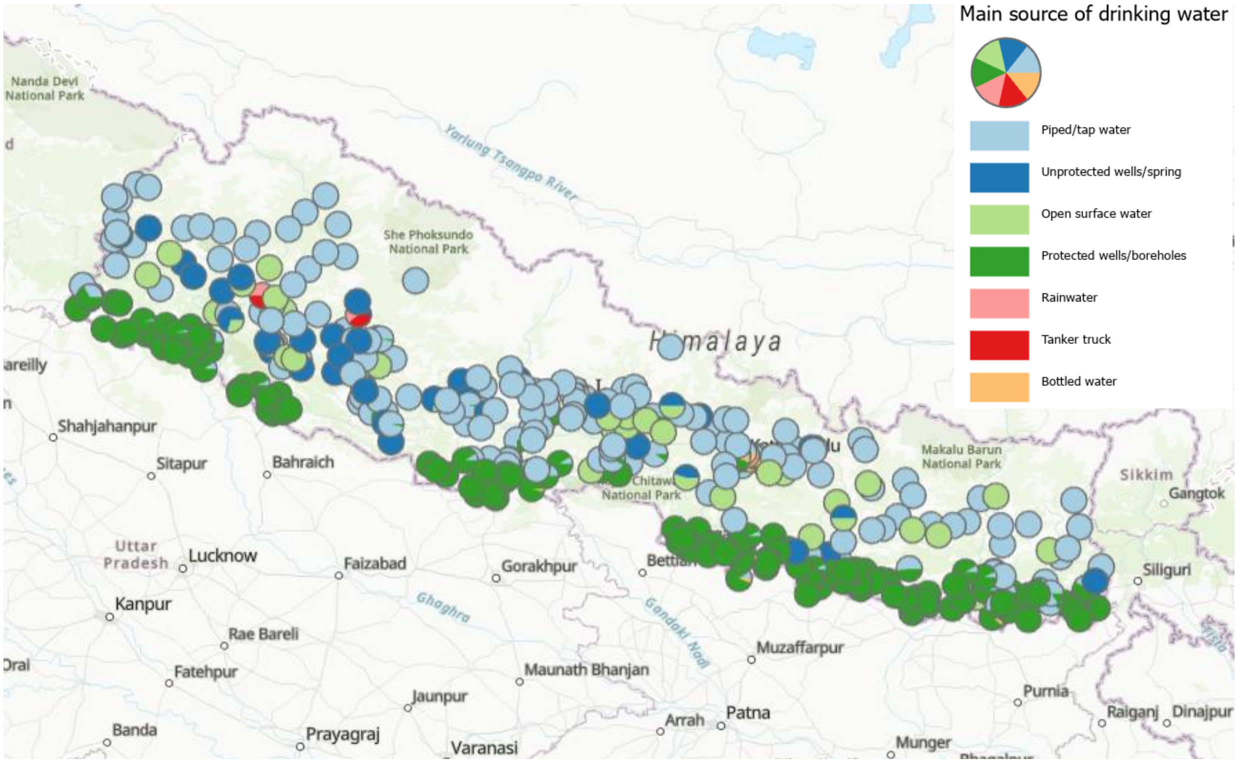
FIGURE 18: Main source of drinking water among women living in hot and cool areas, Cambodia, Wet season (Percentage)



Note: An asterisk "*" indicates improved water source. Clusters are classified as hot if daytime land surface temperatures fall in the top 25 per cent of all values and cool if daytime land surface temperatures fall in the bottom 25 per cent of all values.

Conversely, in Nepal, increases in temperatures correlate with worse access to basic water sources, but geospatial analysis reveals that water infrastructure availability may be affecting this association. Across the hill and mountain regions of the country, where the availability of improved water infrastructure is lower, people are more likely to rely on open surface water, unprotected wells and springs. In turn, across the southernmost regions, which are further from mountain springs and see higher temperatures, tube wells and hand pumps (improved sources) are widely available (figures 19 and 20). Analysis controlling for infrastructure availability remains an area for further research.

FIGURE 19: Main source of drinking water among women, by cluster, Nepal



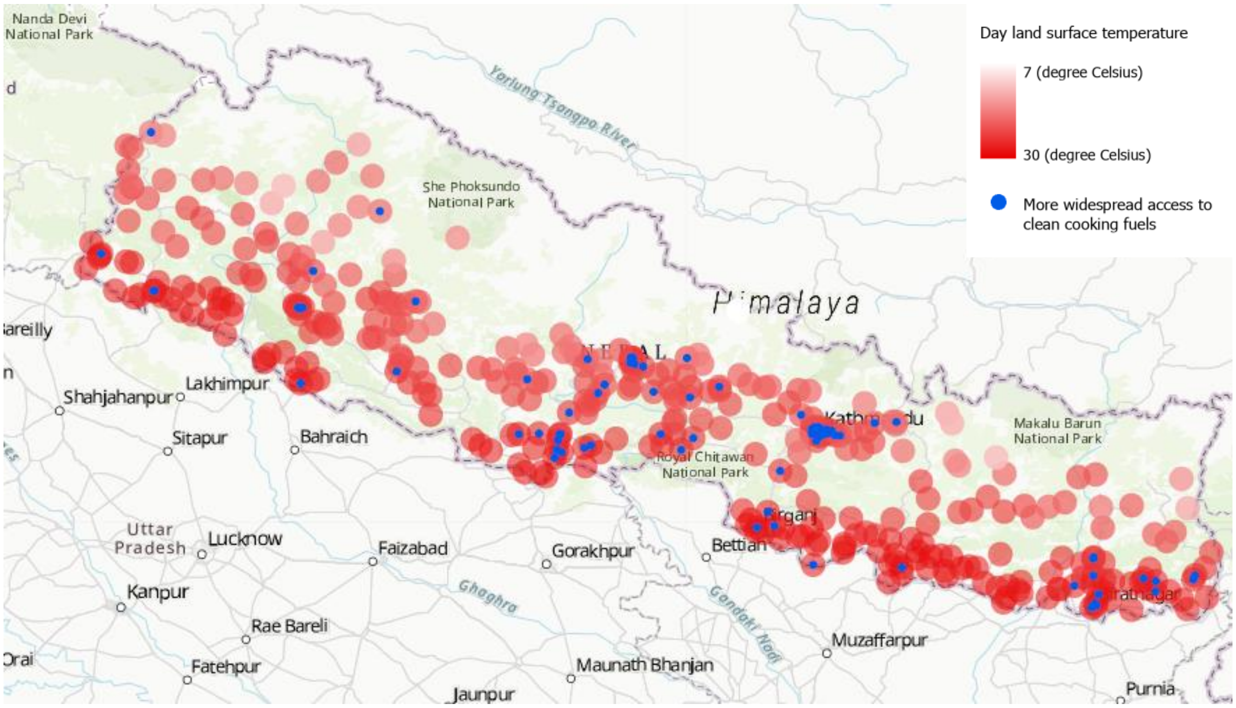
Key for interpretation: The map shows pie charts with the distribution of types of drinking water sources across clusters in Nepal.

In the Philippines, as expected, increases in daytime land surface temperatures heighten the risk of using unhealthy fuel. Geospatial analysis confirms that, excluding major cities such as Metro Manila and Cebu (where better fuel infrastructure and LPG availability enable access), cooler clusters are more likely to rely on clean cooking fuel. Economic strains associated with heat-driven reductions in ecosystem productivity, coupled with increased electricity and gas prices as a result of heat,[62] may be prompting people in hot clusters to shift to cheaper but dirtier fuel.

Unexpectedly, in Bangladesh and Nepal, the odds of accessing clean fuel are substantially higher in warmer clusters. In both instances, fuel infrastructure and prices are likely driving this association. In Nepal, the use of clean cooking fuel, such as liquefied petroleum gas (LPG) and biogas, is mostly concentrated in the Central (Kathmandu valley) and Western regions, where fuel infrastructure and the ability to purchase gas tanks exist. In turn, wood is the most widely used form of cooking fuel in cooler mountainous areas, where forests abound[63].

[62] E. De Cian, E. Lanzi and R. Roson (2007). The impact of temperature change on energy demand: a dynamic panel analysis. Available from: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=984237.
[63] N.P. Adhikari and R.C. Adhikari (2021). Geospatial mapping of biomass supply and demand for household energy management in Nepal. *Development Engineering*. Available from: www.sciencedirect.com/science/article/pii/S2352728521000129.

FIGURE 20: Geographical distribution of clusters where women have more widespread access to clean cooking fuel, by average daytime land surface temperature, Nepal



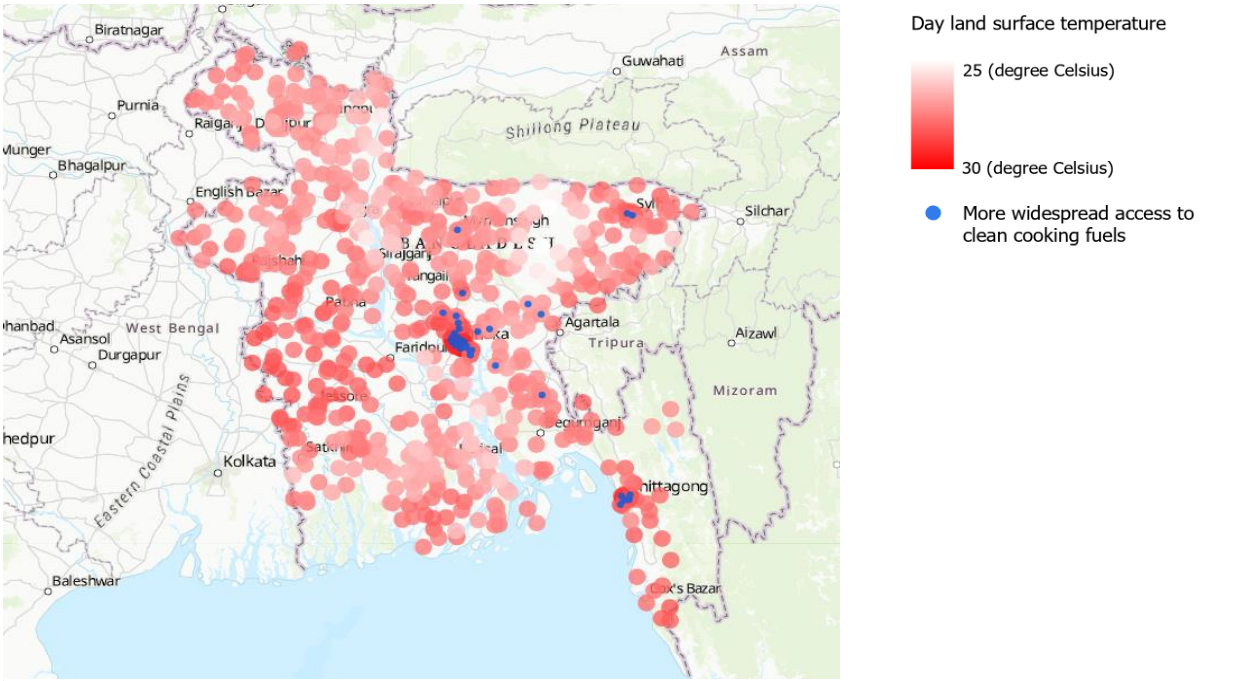
Key for interpretation: The blue markers represent clusters with more widespread access to clean fuel (bottom 25 per cent of cluster values). The map indicates a prevalence of access to clean cooking fuel in warmer regions.

In Bangladesh, the location of clusters using natural gas for cooking (an improved fuel) overlaps largely with the country's distribution of major gas condensate fields and wells (figures 21 and 22). As many of these locations are hot clusters, this contributes to the association – an estimated 40.4 per cent of women living in hot clusters use natural gas, compared to 4.8 per cent in cool clusters (figure 23). Worryingly, oil drilling itself may be contributing to the warming of these areas. Evidence indicates that areas subject to fossil fuel extraction have relatively high rates of temperature rise overall.[64] As extraction operations go on, temperatures in such areas may continue to rise. Although increased access to clean cooking fuel is a positive gender outcome, the negative externalities linked to its extraction could, all in all, be detrimental from a gender perspective as a result of biodiversity loss and environmental degradation.[65] Further analysis with controls for the availability of fuel infrastructure and prices could shed additional light on the connections between temperatures and fuel.

[64] R. Nawaz, A. Sharif and W. Rehman (2019). Earth Thermal Emissions and Global Warming. *Journal of Scientific Research and Reports*. https://journaljsrr.com/index.php/JSRR/article/view/1552

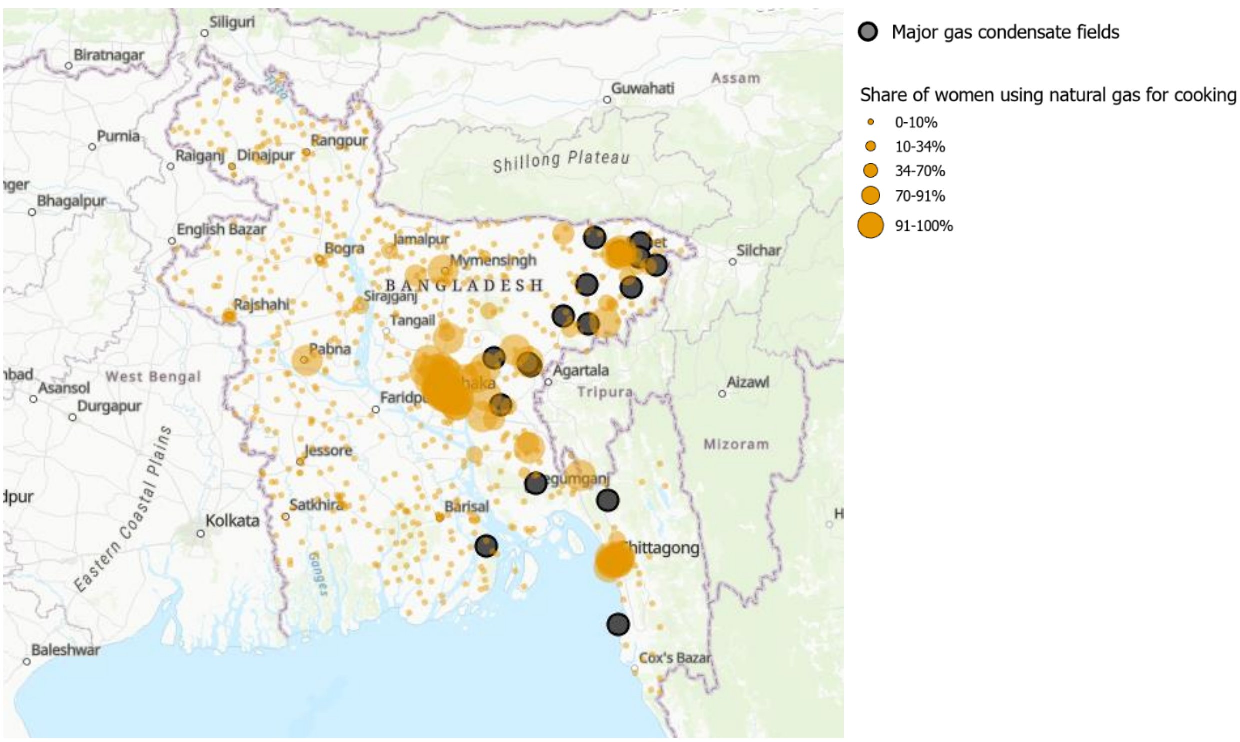
[65] F. Barbir, T.N. Veziroğlu and H.J. Plass Jr. (1990). Environmental damage due to fossil fuels use. *International journal of hydrogen energy*, vol 15, Issue 10. Available from: www.sciencedirect.com/science/article/pii/036031999090005J; and S. Bertrand (2021). Climate, Environmental, and Health Impacts of Fossil Fuels. Available from: www.eesi.org/papers/view/fact-sheet-climate-environmental-and-health-impacts-of-fossil-fuels-2021.

FIGURE 21: Geographical distribution of clusters where women have more widespread access to clean cooking fuel, by average daytime land surface temperature, Bangladesh



Key for interpretation: The blue markers represent clusters with better access to clean cooking fuel (bottom 25 per cent of cluster values). The map indicates a higher prevalence of access to clean fuel across warmer clusters.

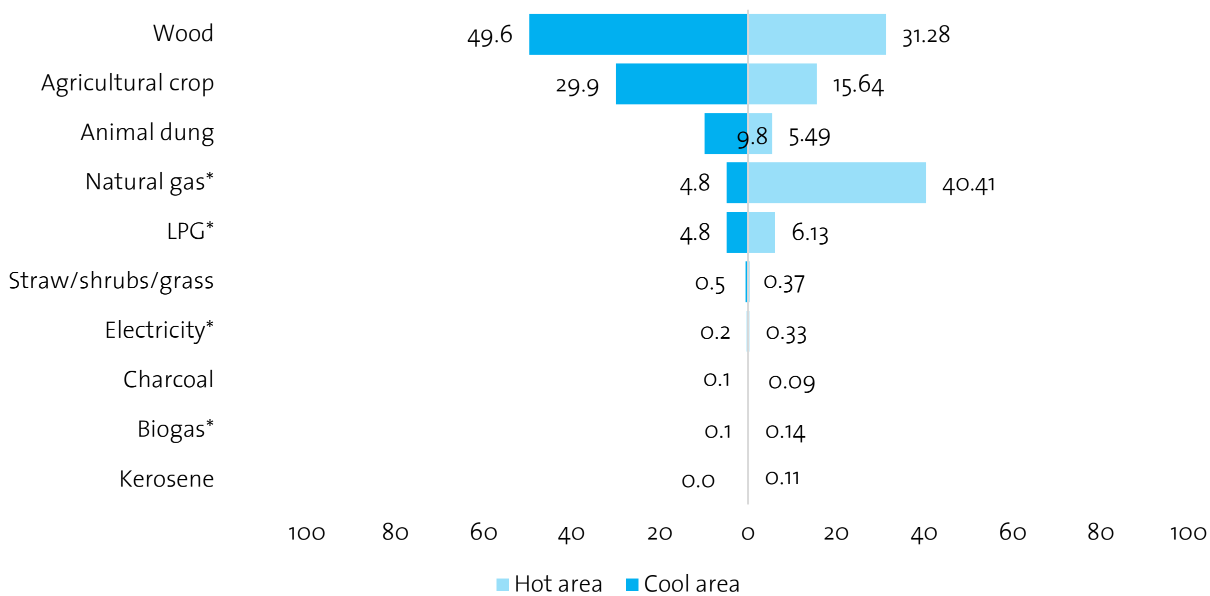
FIGURE 22: Major gas fields and share of women using natural gas as a cooking fuel, Bangladesh



Key for interpretation: The black markers represent major gas fields, and the yellow markers' size is proportional to the share of women that rely on natural gas for cooking (cluster average). The map shows that natural gas use is more widespread in clusters near gas fields.

Source: Data on major gas condensate fields from J.A. Curiale et al. (2002). Origin of petroleum in Bangladesh. Available from: https://pubs.geoscienceworld.org/aapgbull/article-abstract/86/4/625/39983.

FIGURE 23: Main source of cooking fuel among women living in hot and cool areas, Bangladesh (Percentage)



Note: An asterisk "*" indicates clean cooking fuel. Clusters are classified as hot if day land surface temperature values fall in the top 25 per cent of all values and cool if day land surface temperature values fall in the bottom 25 per cent of all values.

6. CONCLUSION

The purpose of the study was to test the association between climate change factors and gender related outcomes, which was achieved by analysing DHS data integrated with geospatial data. Random forest (a machine learning algorithm) was used to ascertain the importance of climate change variables in classifying women into groups at high or low risk of experiencing selected gender related outcomes, while a multivariate binary logistic regression model was used to measure the degree and direction of these associations. **Findings support the hypothesis that factors related to climate change are associated with gender outcomes in all countries considered for the study**. This remained true even after controlling for selected socio-demographic variables.

Random forest highlighted multiple climate variables as important to explain the risk of detrimental gender outcomes. Across all countries, proximity to lakes and/or coastlines appear to be particularly important in determining the risk of lacking access to basic water sources, using unhealthy cooking fuel and experiencing child marriage and adolescent births. Similarly, aridity, droughts, increases in temperature and flood risk all had important explanatory power over child marriage rates, adolescent births, access to clean water and fuel, with some differences across countries.

Not surprisingly, of all outcomes considered, variables related to climate change had the largest effects on the risk of lacking access to basic drinking water sources and clean cooking fuel. Conversely, climate related variables had the lowest classification power over IPV, although rainfall, aridity and temperatures matter in Timor-Leste and the Philippines.

Logistic regression indicated that increases in drought episodes, temperatures and aridity are associated with worsening gender outcomes. In particular, temperature rises are associated with more prevalent child marriage and adolescent births in Bangladesh, Nepal and Cambodia – countries where child marriage is a more common practice.[66] More frequent drought episodes are linked with the lack of access to basic drinking water sources (Bangladesh and Cambodia), and lack of access to clean fuel for cooking (Bangladesh and the Philippines).[67] Increases in relative aridity (low aridity index) also correlate with worsening gender related outcomes (child marriage and adolescent birth rates in Bangladesh and Nepal), although these effects are smaller in size in all countries except for Timor-Leste where IPV, access to basic water sources and use of unclean fuel increase substantially in arid clusters.

Further analysis is needed to ascertain the causes of these connections and their effects across different population groups and over time. As literature highlights that disadvantaged groups may suffer from climate change disproportionately,[68] further analysis with multiple disaggregation by sex and ethnicity, for instance, could provide additional insights. Longitudinal analysis to explore whether the impact of climate factors may be changing over time could also provide further clarity on these connections.

The implications of the findings presented in this paper could be useful to inform the development of policies and further research. They show that effects related to climate change may hinder the achievement of the Sustainable Development Goals in Asia, in particular Goal 5 (gender equality), Goal 6 (clean water and sanitation) and Goal 7 (affordable and clean energy). They provide empirical evidence on the importance of addressing climate change and gender equality in tandem to achieve transformative results.

[66] They are also connected with the availability of basic water sources and clean cooking fuel, but the direction of these associations differs across countries due to additional factors such as infrastructure and prices.
[67] In Nepal the association with basic drinking water sources appears inverse, likely due to differences in water infrastructure across regions.
[68] A. Sevoyan and G. Hugo (2014). Vulnerability to climate change among disadvantaged groups: the role of social exclusion. In J.P. Palutikof et al. (eds), *Applied Studies in Climate Adaptation*. Available from: https://books.google.com/books?hl=en&lr=&id=8IkeBQAAQBAJ&oi=fnd&pg=PA258&dq=impact+of+climate+change+AND+disadvantaged&ots=WxYeTuSP2f&sig=7-P_mxLheyGHxznk5Me3XGoFjzY

7. ANNEXES

Annex 1: Summary statistics of gender-inequality outcomes by country

TABLE A1.1: Summary statistics for "child marriage", by country

Country	Observations	Mean	Std. dev.	Min.	First quartile	Median	Third quartile	Max.
Bangladesh	21 269	0.67	0.47	0	0	1	1	1
Cambodia	15 772	0.24	0.43	0	0	0	0	1
Nepal	11 294	0.48	0.5	0	0	0	1	1
Philippines	21 835	0.15	0.36	0	0	0	0	1
Timor-Leste	10 561	0.18	0.39	0	0	0	0	1

TABLE A1.2: Summary statistics for “adolescent birth”, by country

Country	Observations	Mean	Std. dev.	Min.	First quartile	Median	Third quartile	Max.
Bangladesh	21 269	0.40	0.49	0	0	0	1	1
Cambodia	15 772	0.1	0.29	0	0	0	0	1
Nepal	11 294	0.2	0.4	0	0	0	0	1
Philippines	21 835	0.08	0.27	0	0	0	0	1
Timor-Leste	10 561	0.09	0.28	0	0	0	0	1

TABLE A1.3: Summary statistics for “intimate partner violence in past 12 months”, by country

Country	Observations	Mean	Std. dev.	Min.	First quartile	Median	Third quartile	Max.
Cambodia	3 472	0.11	0.31	0	0	0	0	1
Nepal	3 757	0.11	0.32	0	0	0	0	1
Philippines	13 135	0.05	0.23	0	0	0	0	1
Timor-Leste	3 672	0.35	0.48	0	0	0	1	1

Note: Due to data availability issues, the analysis excluded data from Bangladesh.

TABLE A1.4: Summary statistics for “no access to basic drinking water sources”, by country

Country	Observations	Mean	Std. dev.	Min.	First quartile	Median	Third quartile	Max.

Bangladesh	18 412	0.04	0.19	0	0	0	0	1
Cambodia	15 300	0.33	0.47	0	0	0	1	1
Dry season								
Wet season	15 293	0.17	0.37	0	0	0	0	1
Nepal	10 772	0.06	0.24	0	0	0	0	1
Philippines	21 609	0.05	0.21	0	0	0	0	1
Timor-Leste	10 197	0.2	0.4	0	0	0	0	1

TABLE A1.5: Summary statistics for "no access to clean fuel", by country

Country	Observations	Mean	Std. dev.	Min.	First quartile	Median	Third quartile	Max.
Bangladesh	21 238	0.79	0.41	0	1	1	1	1
Cambodia	15 600	0.81	0.39	0	1	1	1	1
Nepal	10 768	0.66	0.47	0	0	1	1	1
Philippines	21 604	0.45	0.5	0	0	0	1	1
Timor-Leste	10 445	0.89	0.31	0	1	1	1	1

Annex 2: Correlation coefficients of gender-related outcomes with independent and control variables, by country

TABLE A2.1: Correlations in Bangladesh

	Child marriage	Adolescent birth	No access to basic water sources	No access to clean fuel
Drought	0.109	0.079	0.029	0.177
Aridity index	-0.165	-0.107	0.116	-0.083
Rainfall	-0.174	-0.110	0.111	-0.092
Daytime land surface temperature	-0.052	-0.051	-0.018	-0.414
Flood risk 50	-0.030	-0.008	0.008	0.095
Distance to lake	0.040	0.049	0.096	0.093
Distance to seashore	0.064	0.064	-0.104	0.102
Location	0.116	0.093	0.055	0.502
Education	-0.392	-0.333	-0.060	-0.248
Currently employed	0.159	0.142	-0.021	0.146
Age	0.192	0.137	-0.003	0.039
Wealth	-0.211	-0.188	-0.114	-0.566
Proximity to national borders	-0.029	-0.032	-0.110	-0.194
Proximity to protected area	0.021	0.008	-0.097	0.148
Built up index	-0.083	-0.067	-0.021	-0.378

TABLE A2.2: Correlations in Cambodia

	Child marriage	**Adolescent birth**	**Intimate partner violence (last 12 months)**	**No access to basic water sources (dry season)**	**No access to basic water sources (wet season)**	**No access to clean fuel**
Drought	0.077	0.065	-0.021	-0.019	0.072	-0.021
Aridity index	0.010	-0.006	-0.032	0.051	-0.028	0.001
Rainfall	0.041	0.033	-0.014	-0.006	0.009	-0.074
Daytime land surface temperature	-0.008	-0.023	-0.022	-0.016	-0.074	0.095
Flood risk 50	-0.005	-0.014	-0.016	-0.105	-0.039	0.018
Distance to lake	0.059	0.049	0.004	0.051	-0.032	0.036
Distance to seashore	0.014	0.028	0.047	0.096	0.109	0.114

Location	0.097	0.061	0.064	0.359	0.207	0.498
Education	-0.217	-0.157	-0.139	-0.245	-0.177	-0.329
Currently employed	-0.003	0.014	-0.004	-0.036	0.007	-0.050
Age	0.094	0.062	0.017	0.008	0.018	0.042
Wealth	-0.109	-0.073	-0.133	-0.487	-0.326	-0.584
Proximity to national borders	-0.059	-0.049	-0.005	0.081	0.135	0.070
Proximity to protected area	-0.063	-0.048	-0.016	-0.149	-0.082	-0.194
Built up index	-0.088	-0.057	-0.040	-0.235	-0.135	-0.458

TABLE A2.3: Correlations in Nepal

	Child marriage	Adolescent birth	Intimate partner violence (last 12 months)	No access to basic water sources	No access to clean fuel
Drought	-0.061	-0.056	0.004	-0.084	-0.205
Aridity index	-0.194	-0.104	-0.062	-0.007	-0.172
Rainfall	-0.102	-0.037	-0.028	-0.028	-0.211
Daytime land surface temperature	0.077	0.047	0.070	-0.086	-0.160
Flood risk 50	-0.025	0.006	0.002	0.005	-0.022
Distance to lake	0.070	0.030	0.070	-0.066	0.061
Distance to seashore	0.026	0.027	-0.008	0.089	0.088
Location	0.087	0.027	-0.008	-0.011	0.293
Education	-0.379	-0.225	-0.097	-0.068	-0.328
Currently employed	0.004	0.003	0.011	0.046	0.150
Age	0.137	0.040	-0.035	0.000	0.003
Wealth	-0.128	-0.069	-0.042	-0.204	-0.674
Proximity to national borders	-0.081	-0.048	-0.047	0.155	0.004
Proximity to protected area	0.089	0.018	0.002	0.019	0.133
Built up index	-0.112	-0.049	0.006	-0.013	-0.344

TABLE A2.4: Correlations in the Philippines

	Child marriage	Adolescent birth	Intimate partner violence (last 12 months)	No access to basic water sources	No access to clean fuel
Drought	0.062	0.043	-0.028	0.070	0.008

Aridity index	-0.006	-0.010	-0.101	0.050	-0.051
Rainfall	0.055	0.040	0.131	0.143	0.174
Daytime land surface temperature	-0.033	-0.038	-0.098	-0.122	-0.168
Flood risk 50	-0.022	-0.015	-0.029	-0.042	-0.016
Distance to lake	0.078	0.048	0.071	0.046	0.084
Distance to seashore	0.046	0.034	0.081	0.135	0.129
Location	0.098	0.072	0.076	0.209	0.256
Education	-0.217	-0.185	-0.084	-0.166	-0.207
Currently employed	0.030	0.029	-0.008	0.032	-0.005
Age	0.069	0.064	-0.033	0.014	0.025
Wealth	-0.112	-0.094	-0.092	-0.294	-0.346
Proximity to national borders	0.023	0.023	0.083	0.156	0.126
Proximity to protected area	-0.038	-0.017	0.003	0.027	-0.001
Built up index	-0.082	-0.050	-0.076	-0.166	-0.183

TABLE A2.5: Correlations in Timor-Leste

	Child marriage	Adolescent birth	Intimate partner violence (last 12 months)	No access to basic water sources	No access to clean fuel
Drought	0.062	0.043	-0.028	0.070	0.008
Aridity index	-0.006	-0.010	-0.101	0.050	-0.051
Rainfall	0.055	0.040	0.131	0.143	0.174
Daytime land surface temperature	-0.033	-0.038	-0.098	-0.122	-0.168
Flood risk 50	-0.022	-0.015	-0.029	-0.042	-0.016
Distance to lake	0.078	0.048	0.071	0.046	0.084
Distance to seashore	0.046	0.034	0.081	0.135	0.129
Location	0.098	0.072	0.076	0.209	0.256
Education	-0.217	-0.185	-0.084	-0.166	-0.207
Currently employed	0.030	0.029	-0.008	0.032	-0.005
Age	0.069	0.064	-0.033	0.014	0.025
Wealth	-0.112	-0.094	-0.092	-0.294	-0.346
Proximity to national borders	0.023	0.023	0.083	0.156	0.126
Proximity to protected area	-0.038	-0.017	0.003	0.027	-0.001
Built up index	-0.082	-0.050	-0.076	-0.166	-0.183

Annex 3: Correlation matrix between key independent variables

FIGURE A3.1: Correlation matrix between key independent variables, Bangladesh

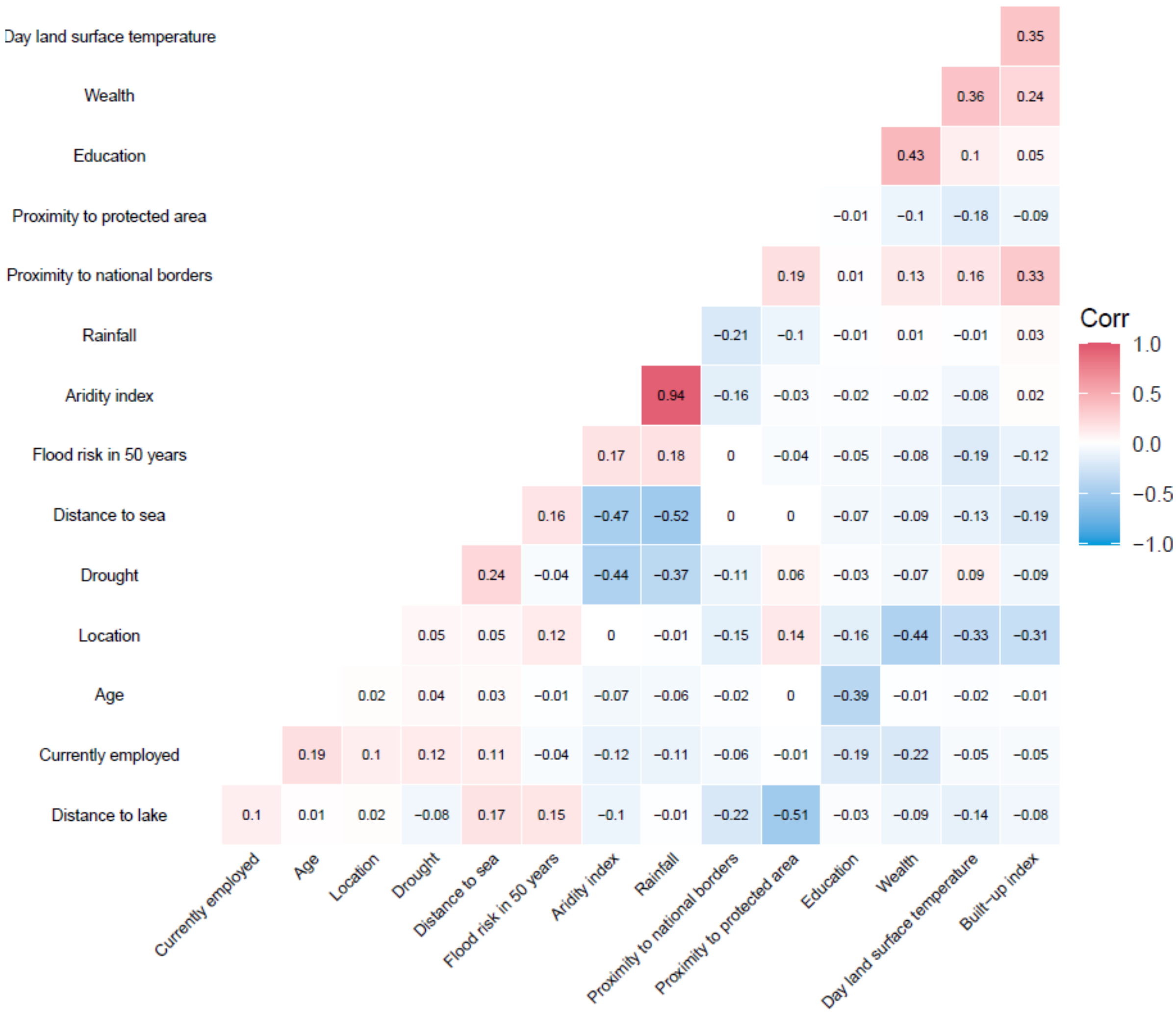


FIGURE A3.2: Correlation matrix between key independent variables, Cambodia

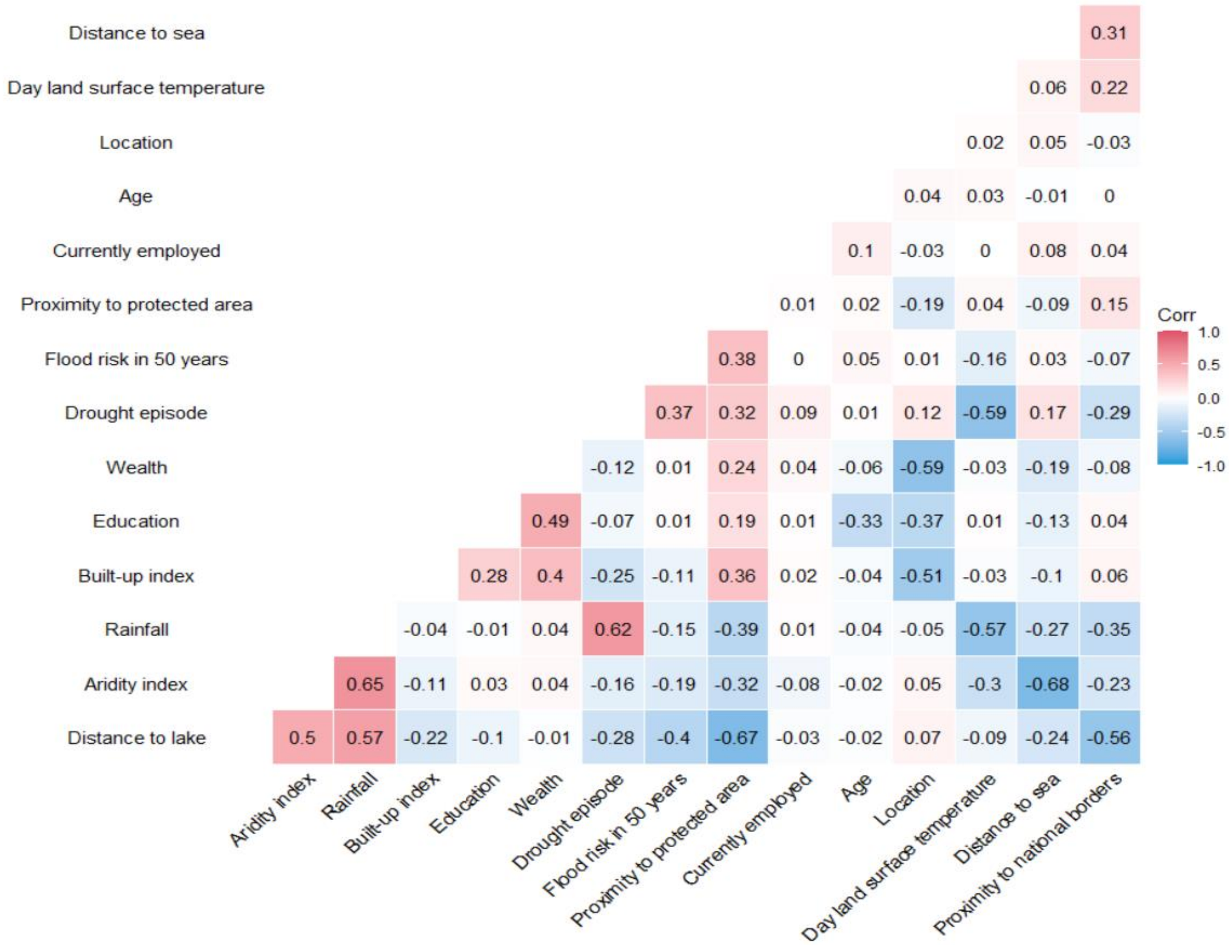


FIGURE A3.3: Correlation matrix between key independent variables, Nepal

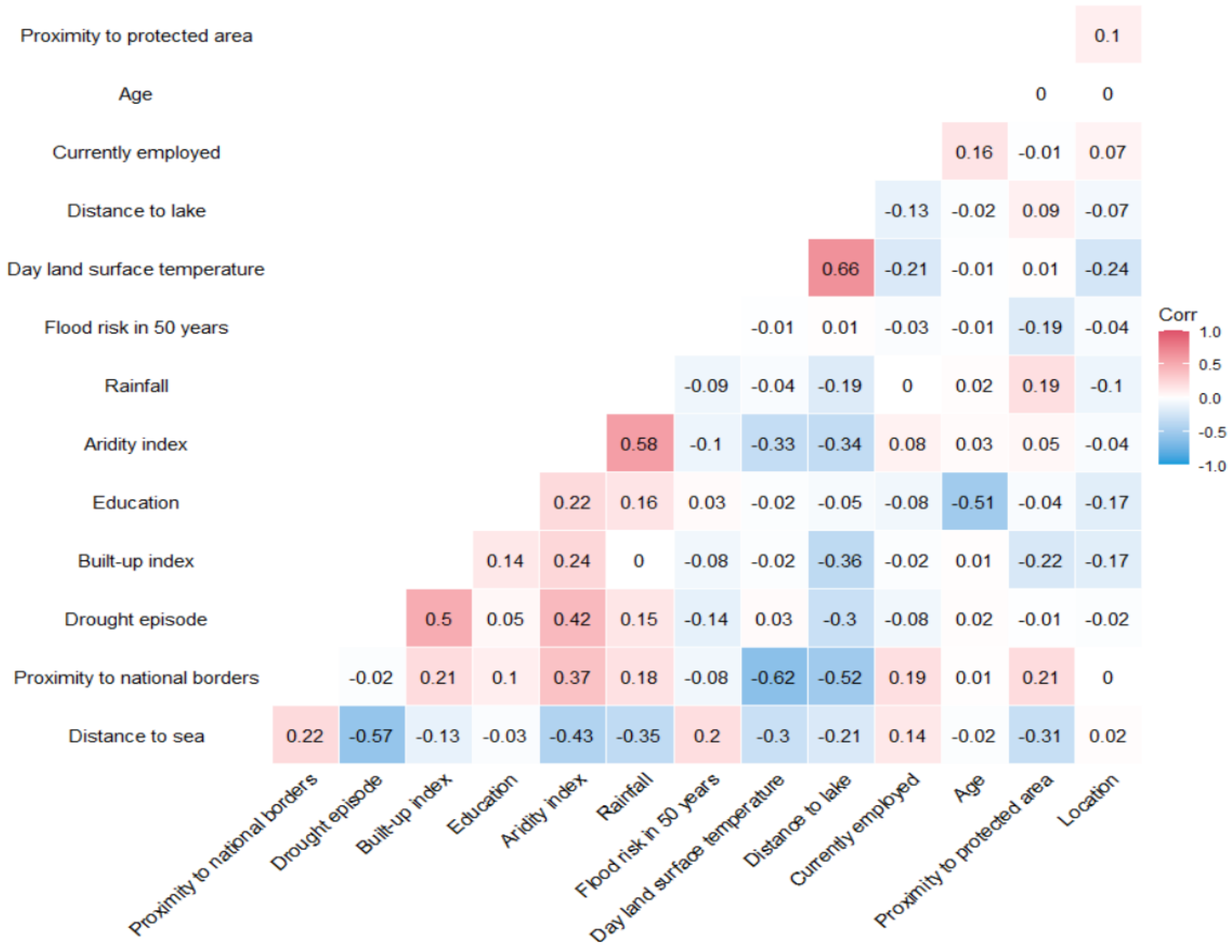


FIGURE A3.4: Correlation matrix between key independent variables, Philippines

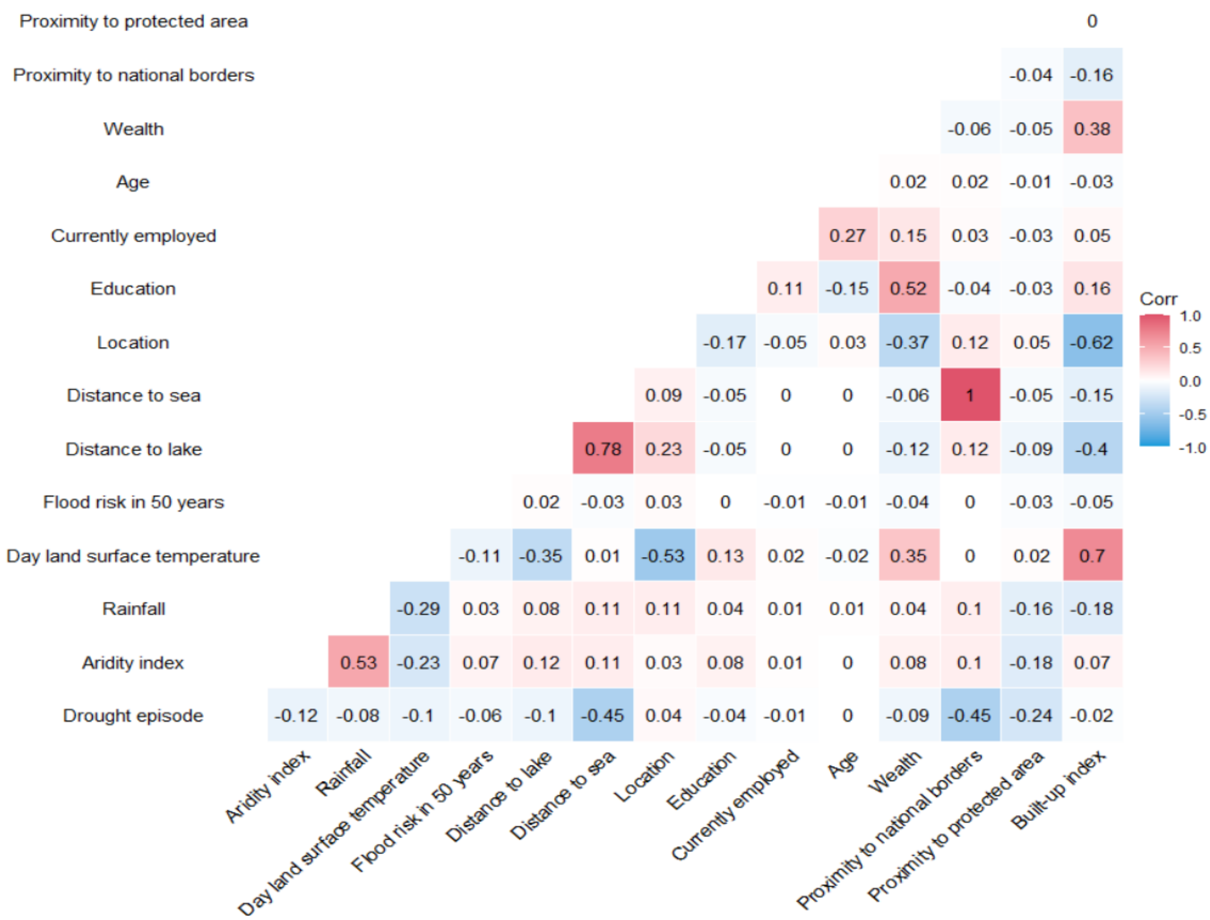
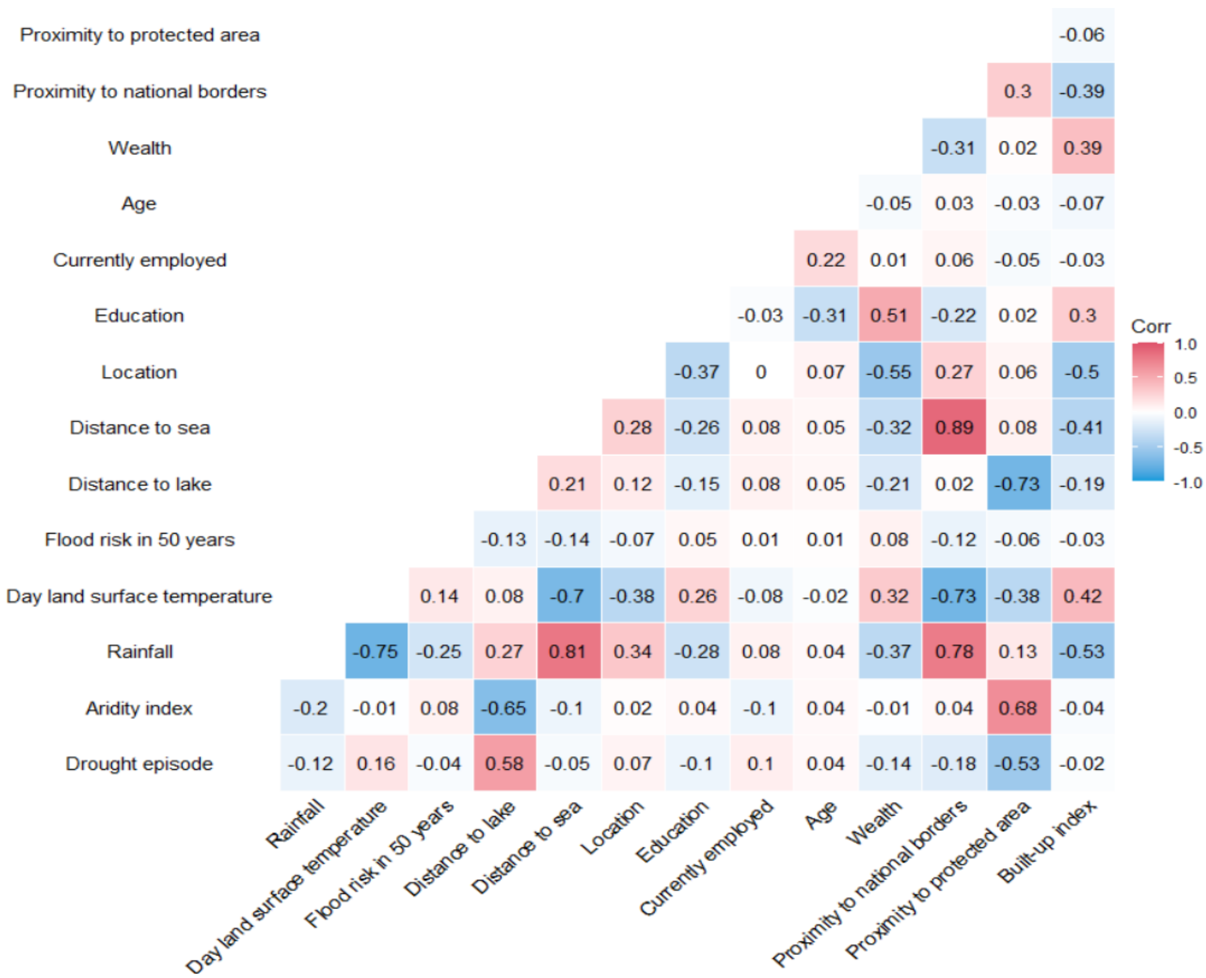


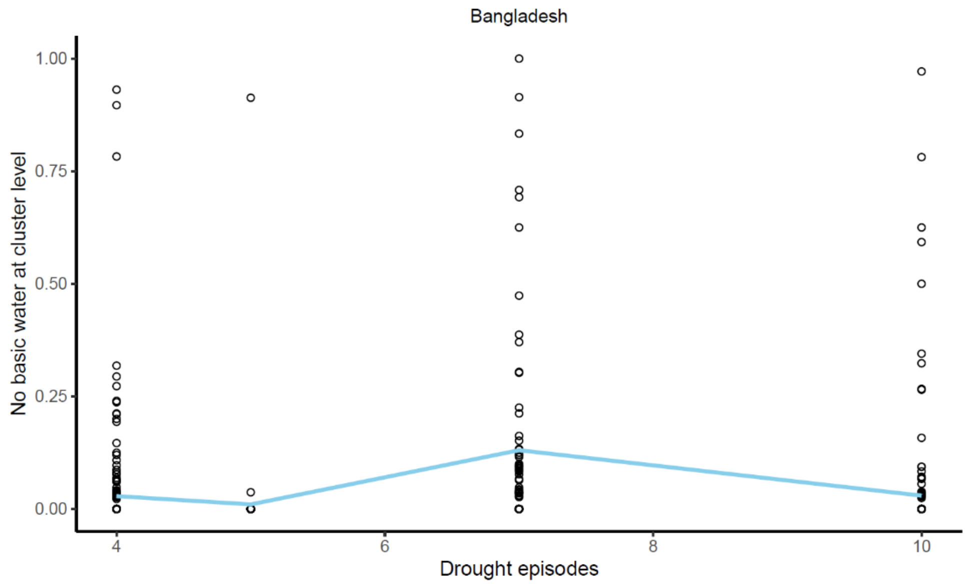
FIGURE A3.5: Correlation matrix between key independent variables, Timor-Leste

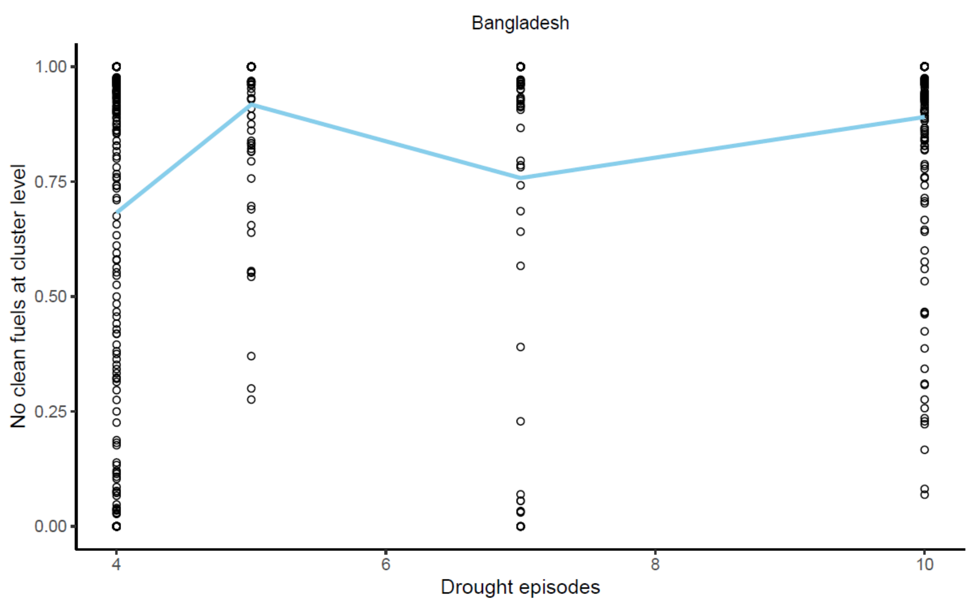


Annex 4: Correlation between gender inequality and key climate variables

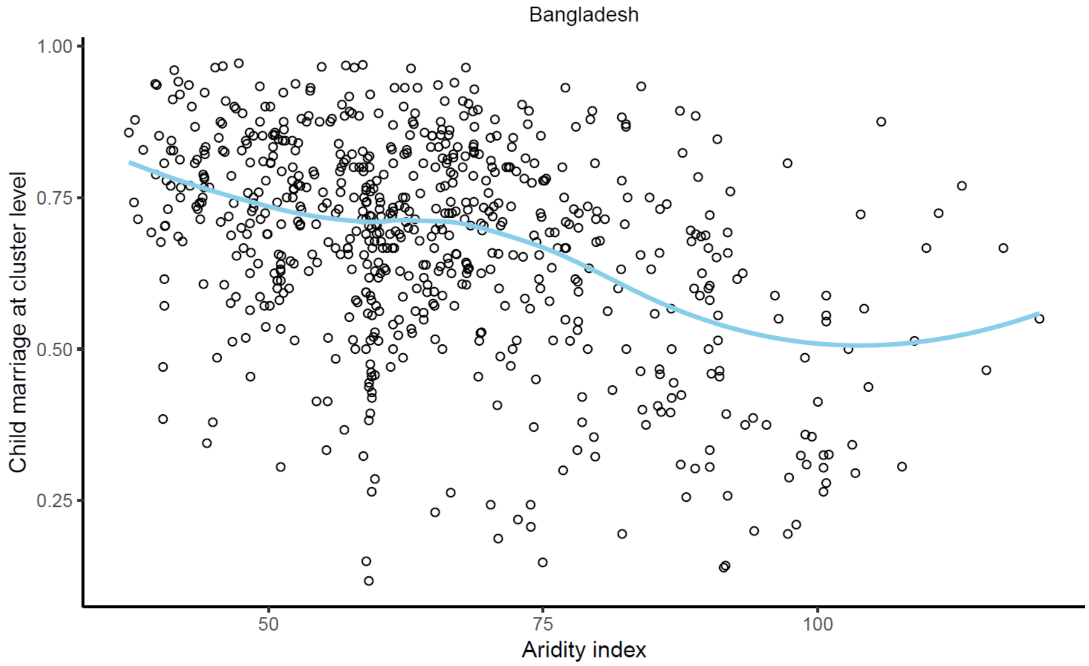
This annex includes only climate variables with statistically significant odds ratios.

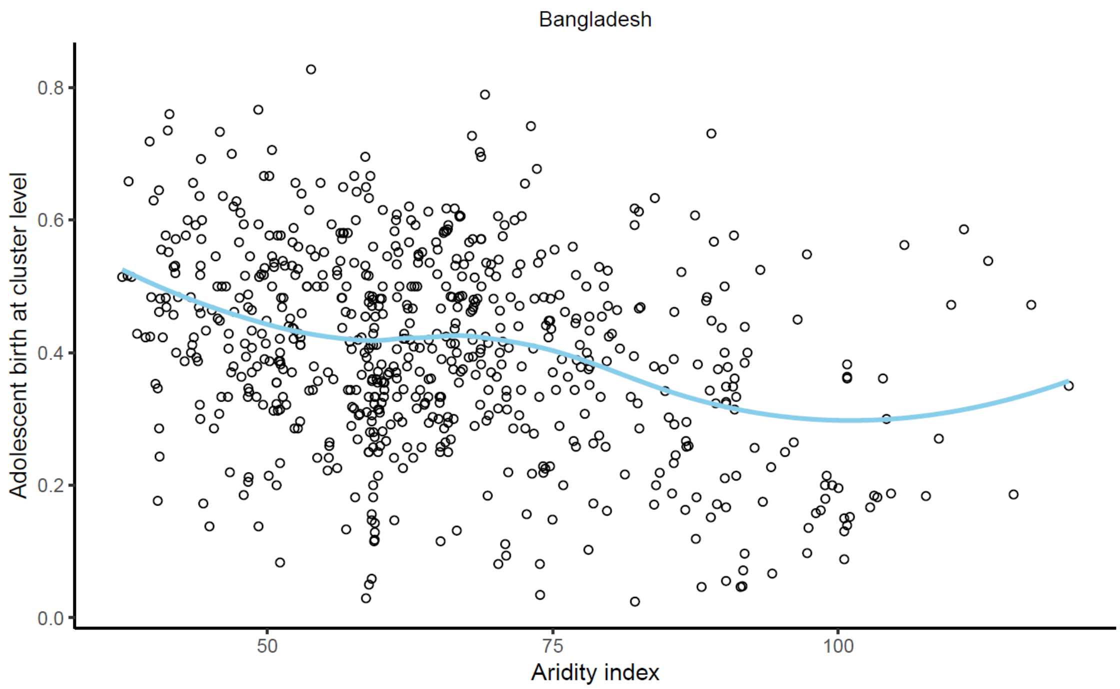
Bangladesh (Drought episodes)

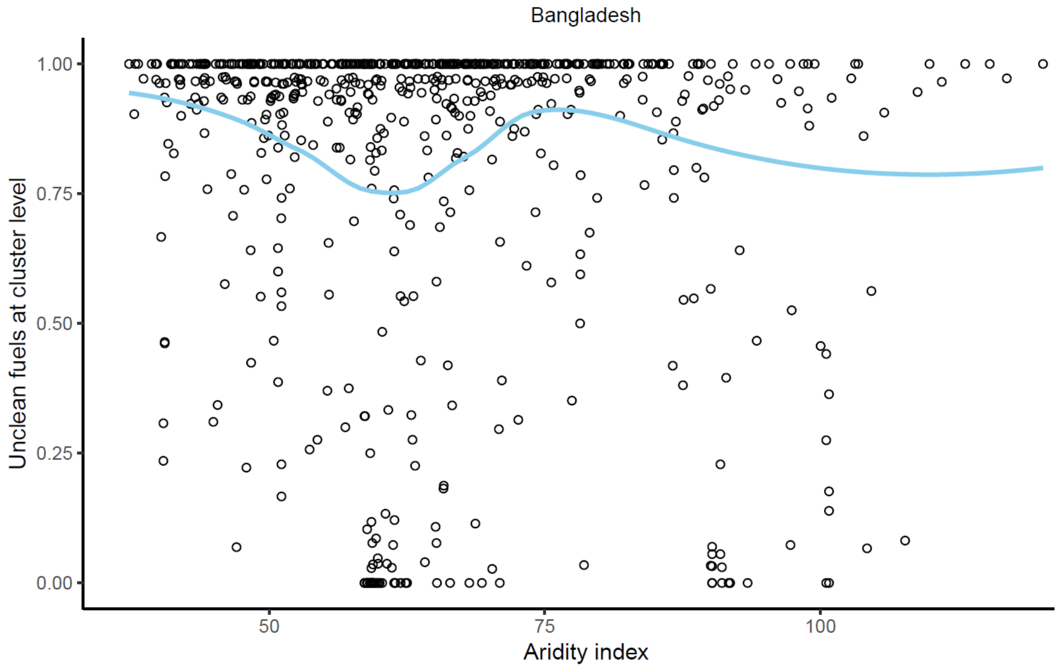




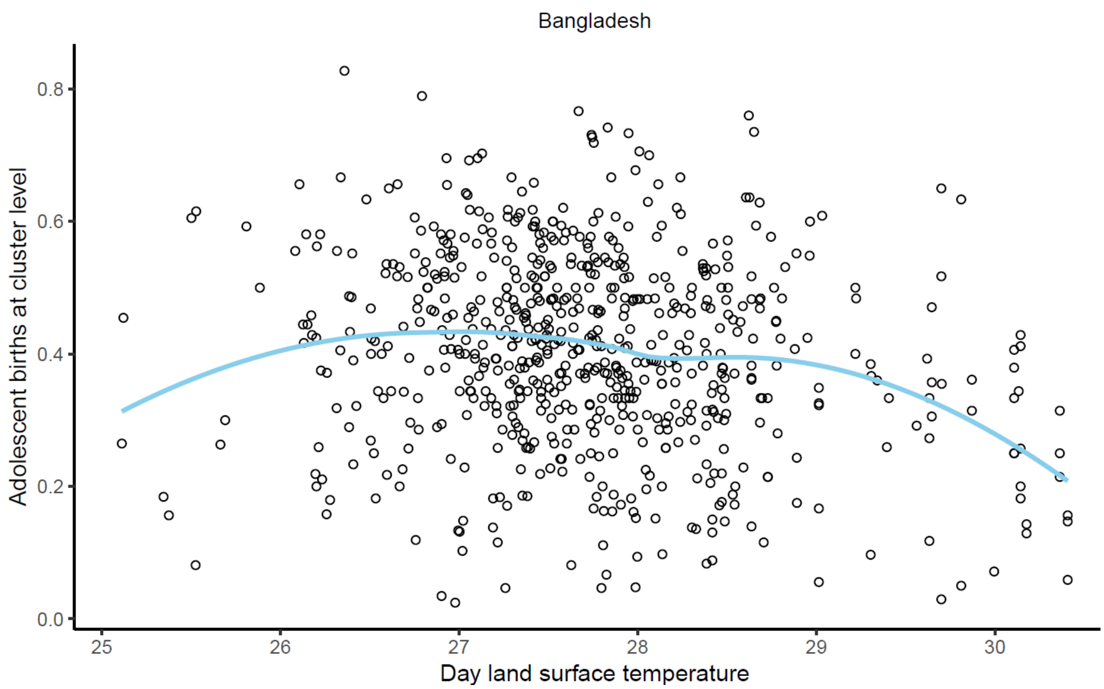
Bangladesh (Aridity index)

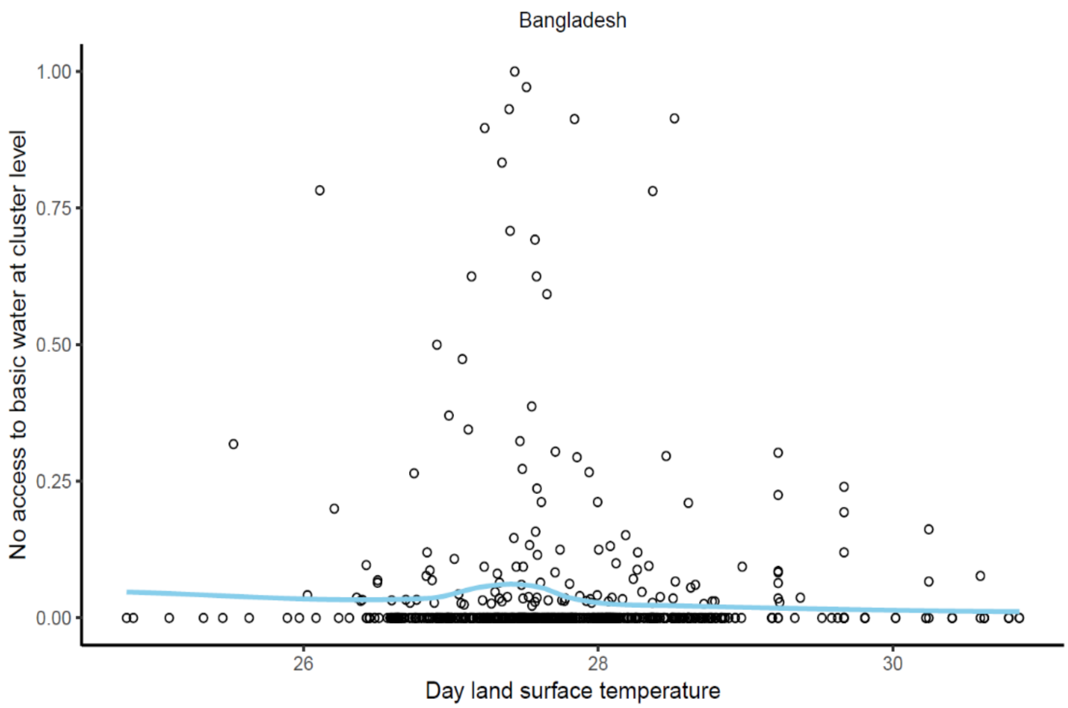


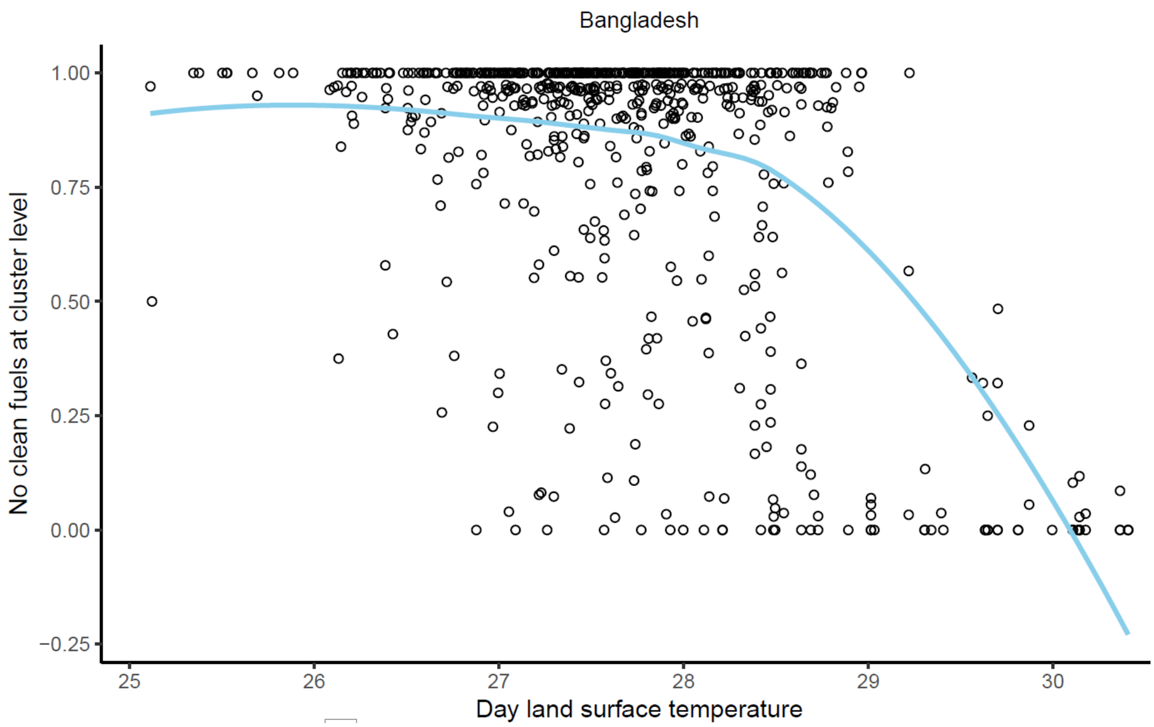

Bangladesh
Adolescent birth at cluster level
0.0
0.2
0.4
0.6
0.8
50
75
100
Aridity index



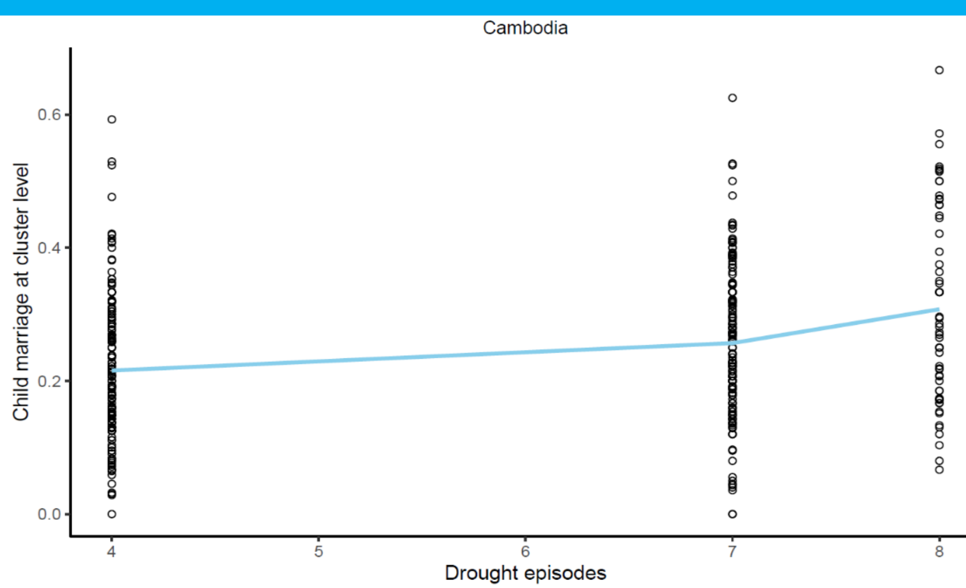
Bangladesh (Day land surface temperature)

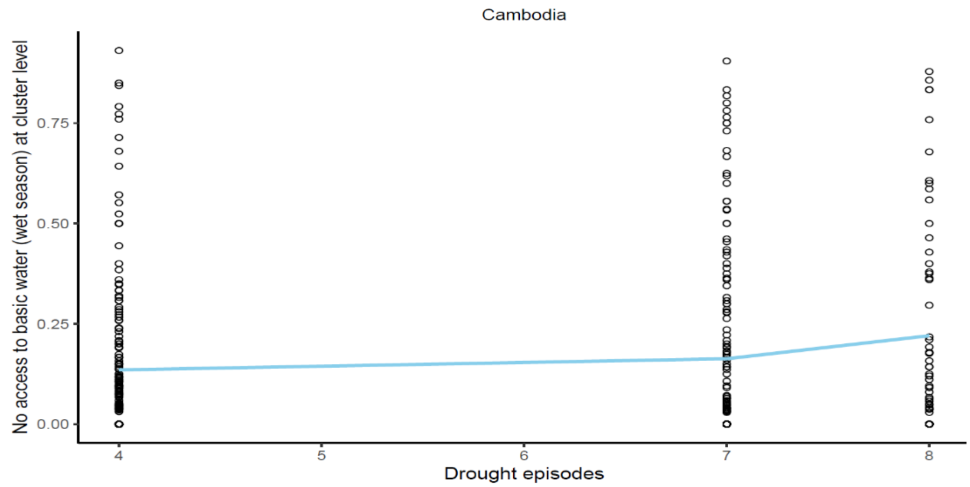


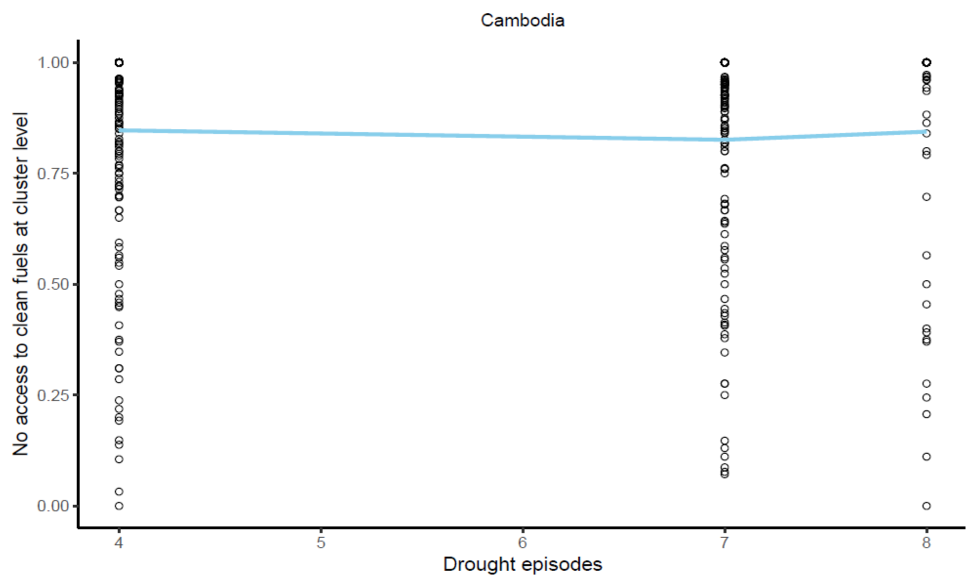

Bangladesh
No access to basic water at cluster level
1.00
0.75
0.50
0.25
0.00
26
28
30
Day land surface temperature



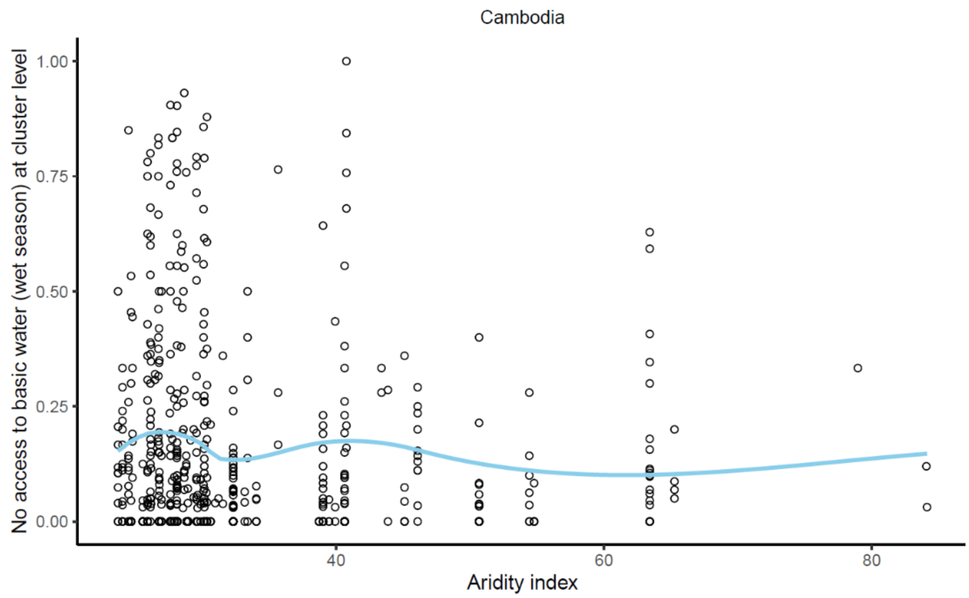
Cambodia (Drought episodes)

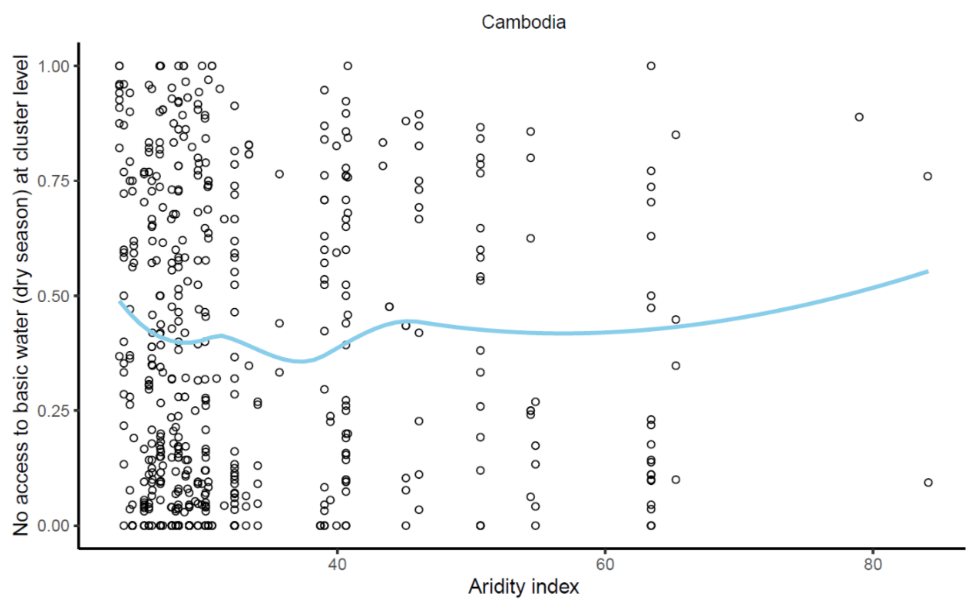




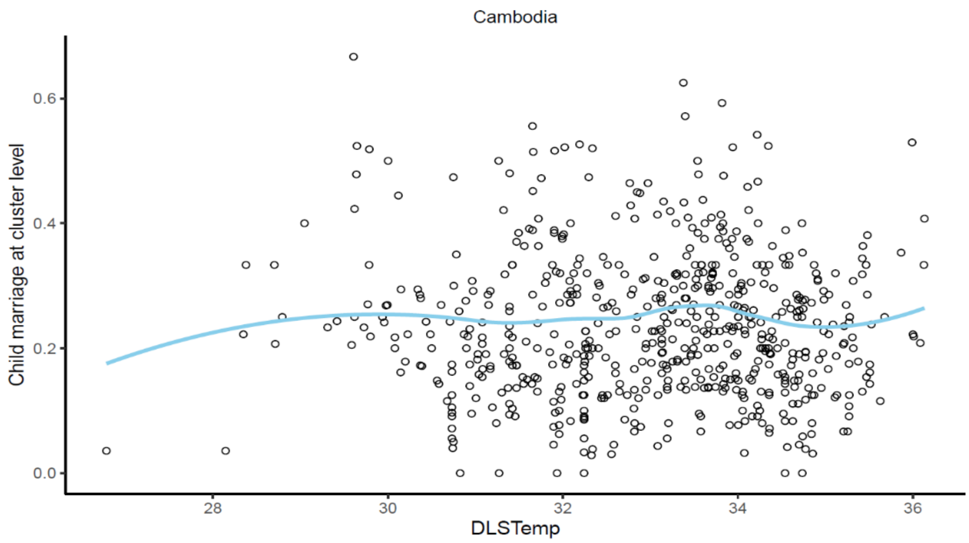


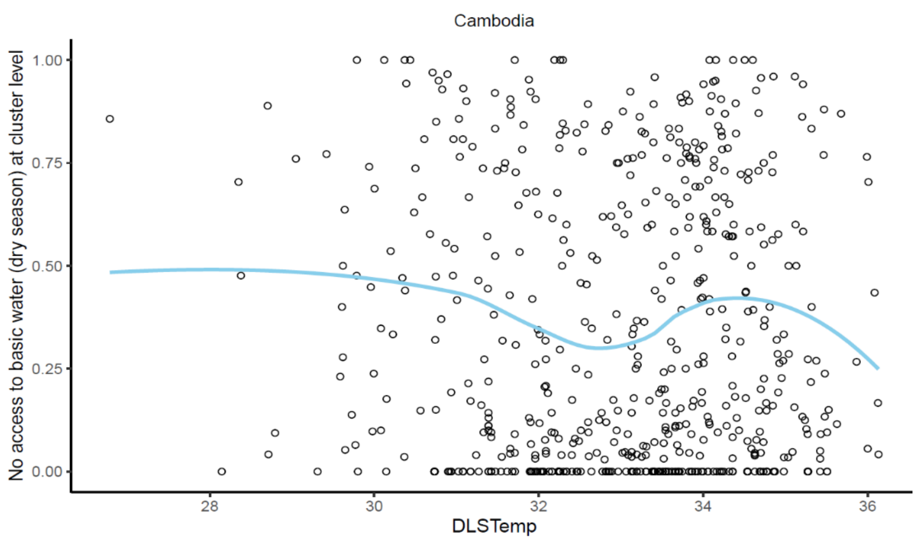
Cambodia (Aridity index)

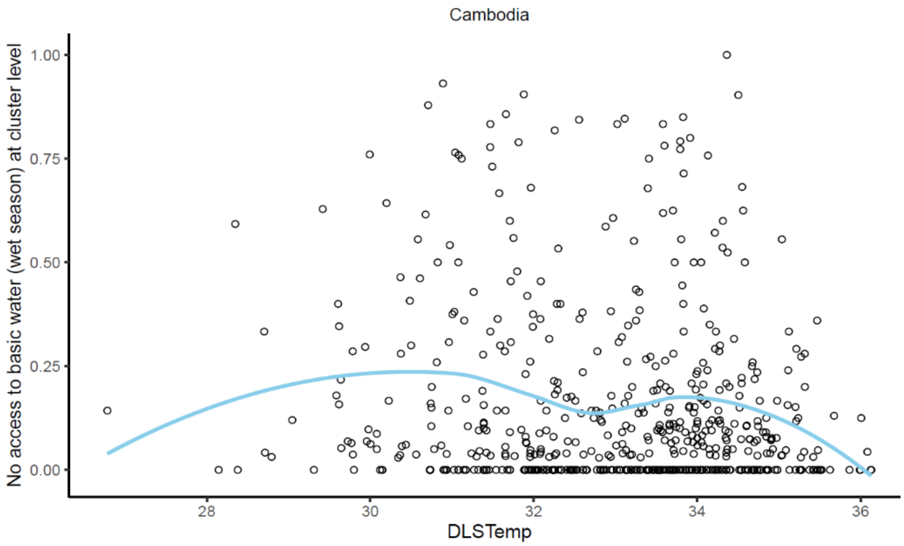

Cambodia
No access to basic water (wet season) at cluster level
1.00
0.75
0.50
0.25
0.00
40
60
80
Aridity index


Cambodia
No access to basic water (dry season) at cluster level
1.00
0.75
0.50
0.25
0.00
40
60
80
Aridity index

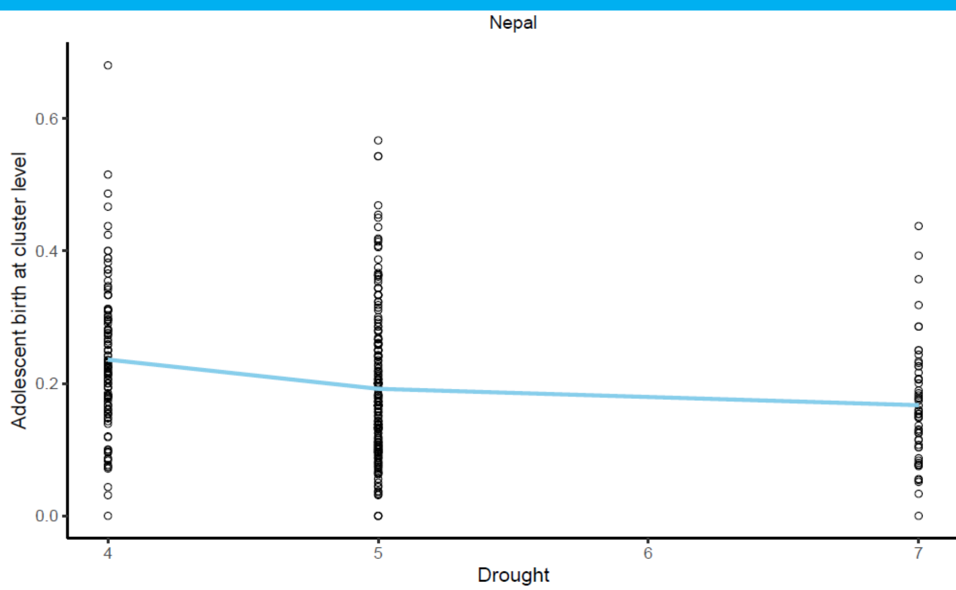
Cambodia (Day land surface temperature)

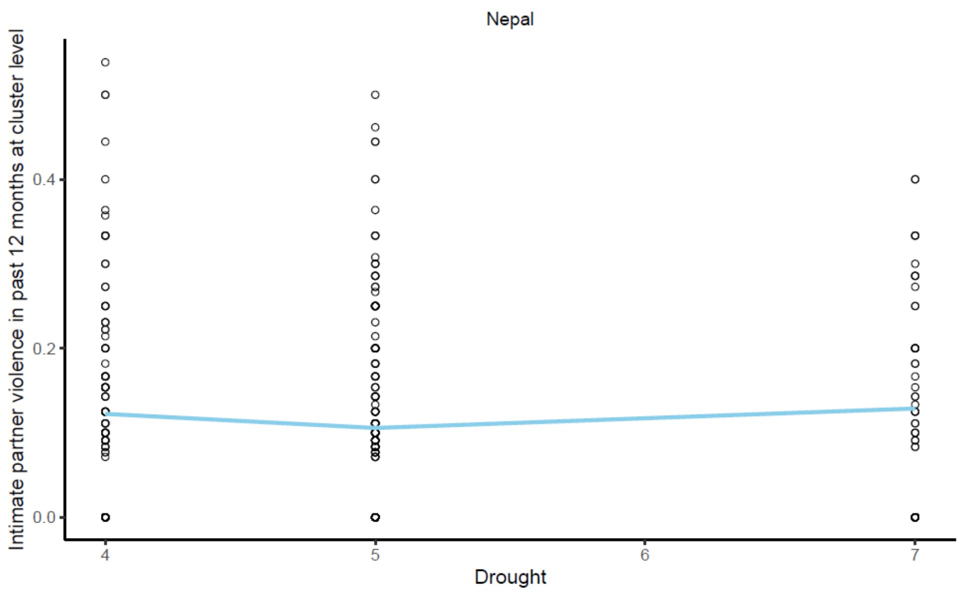


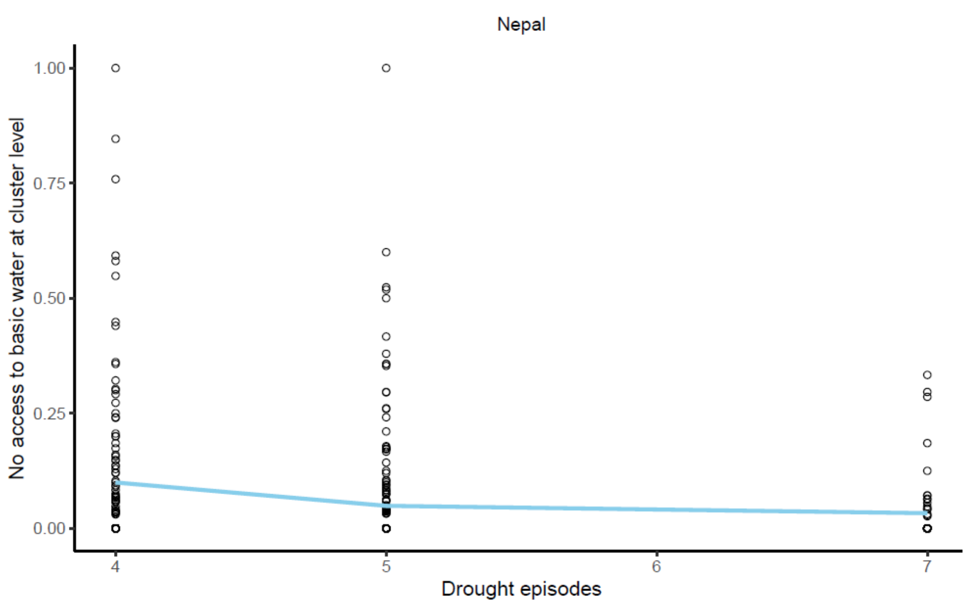




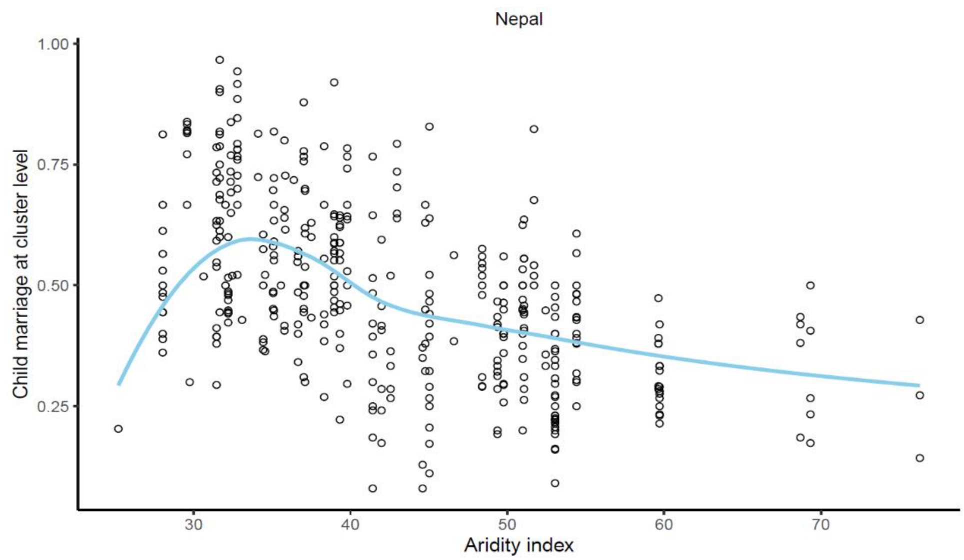
Nepal (Drought episodes)

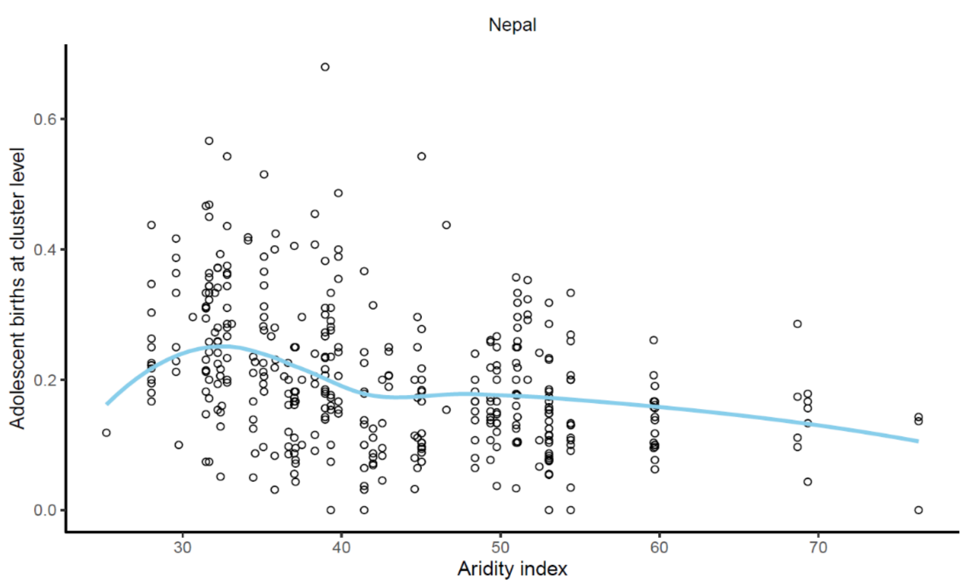


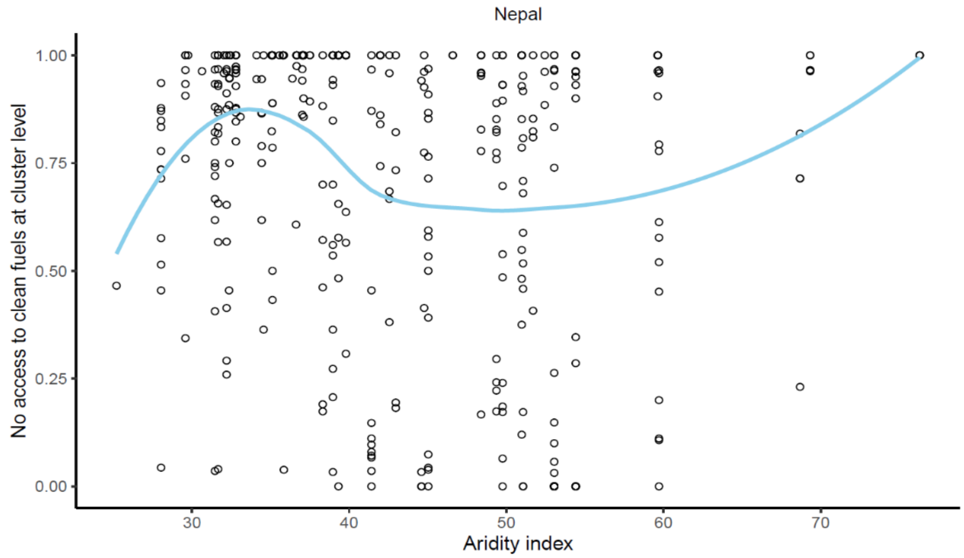




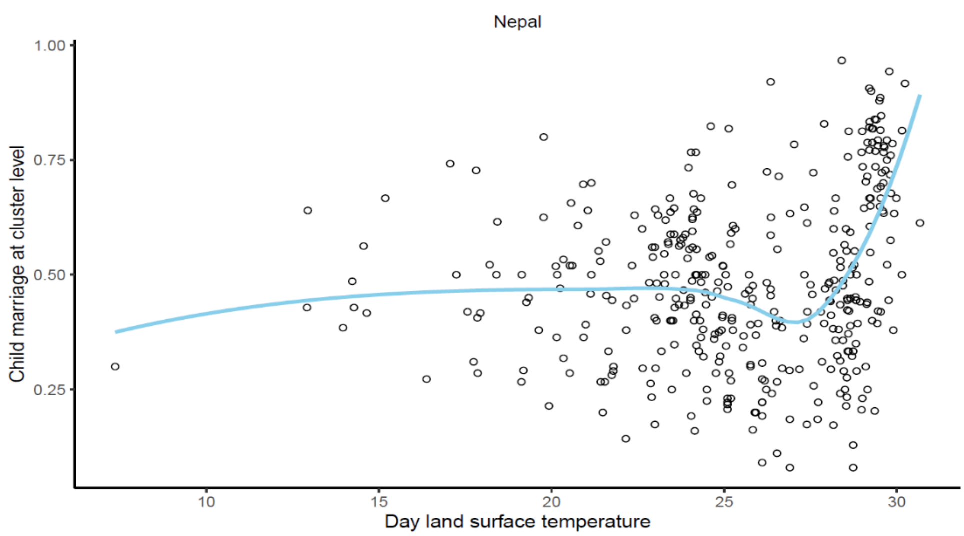
Nepal (Aridity index)

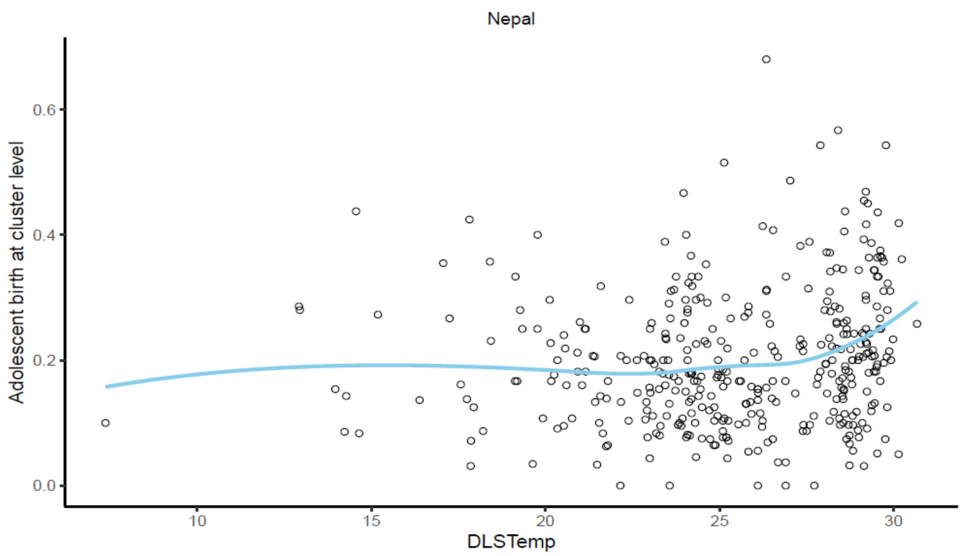

Nepal
Child marriage at cluster level
1.00
0.75
0.50
0.25
30
40
50
60
70
Aridity index


Nepal
Adolescent births at cluster level
0.6
0.4
0.2
0.0
30
40
50
60
70
Aridity index

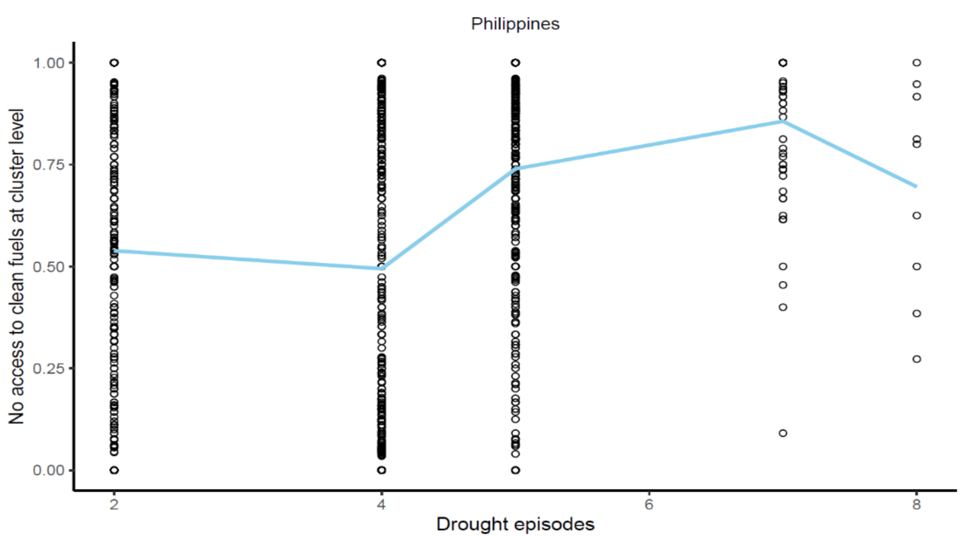


Nepal (Day land surface temperature)

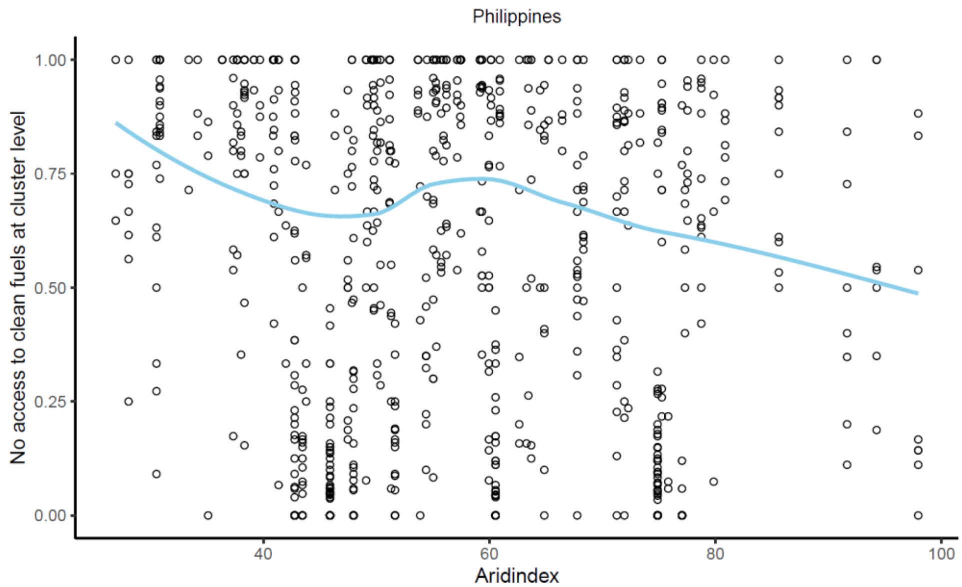




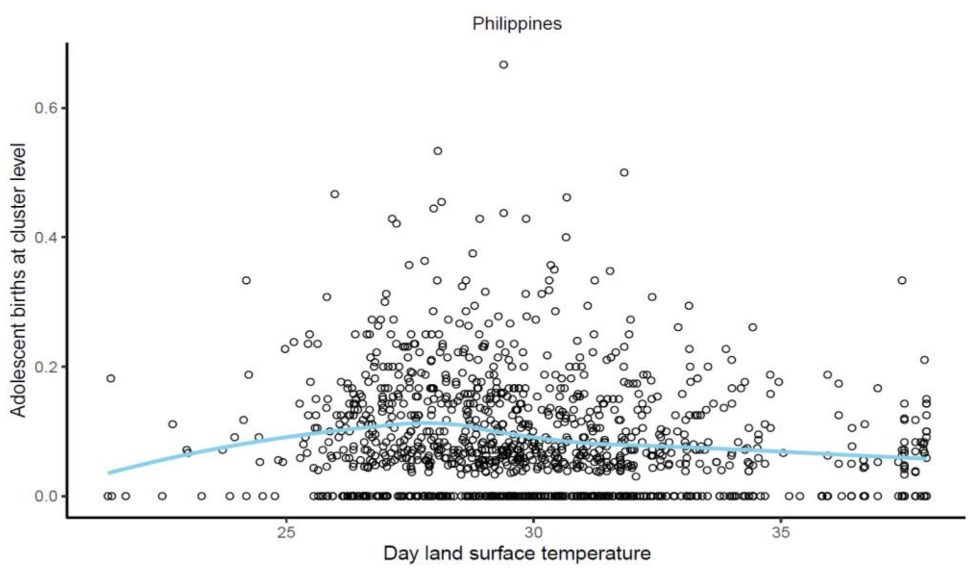
Philippines (Drought)

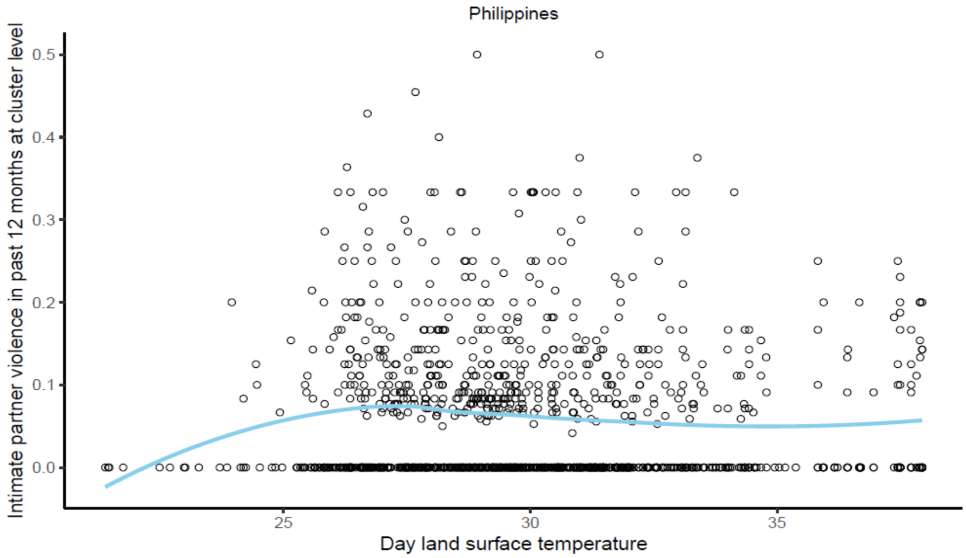


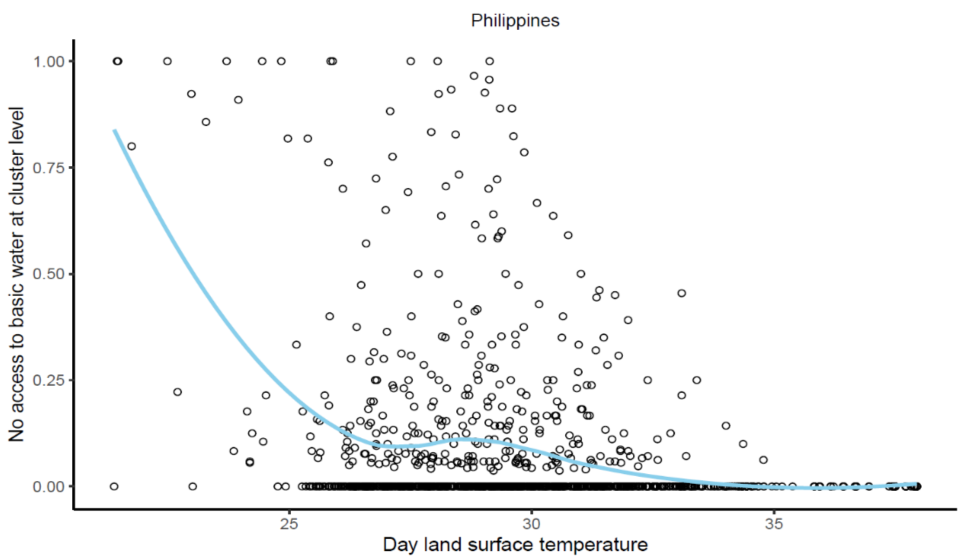
Philippines (Aridity index)

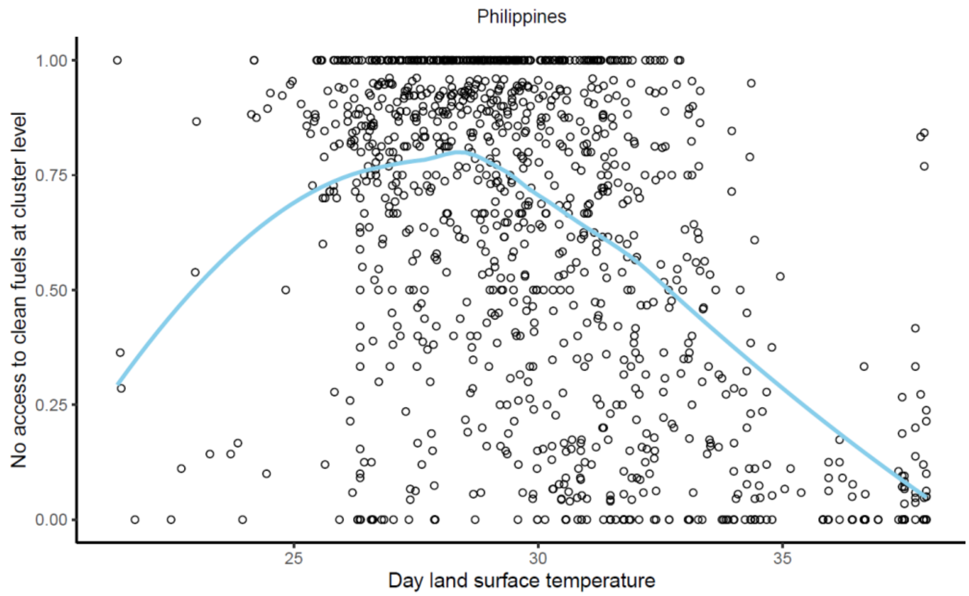


Philippines (Day land surface temperature)

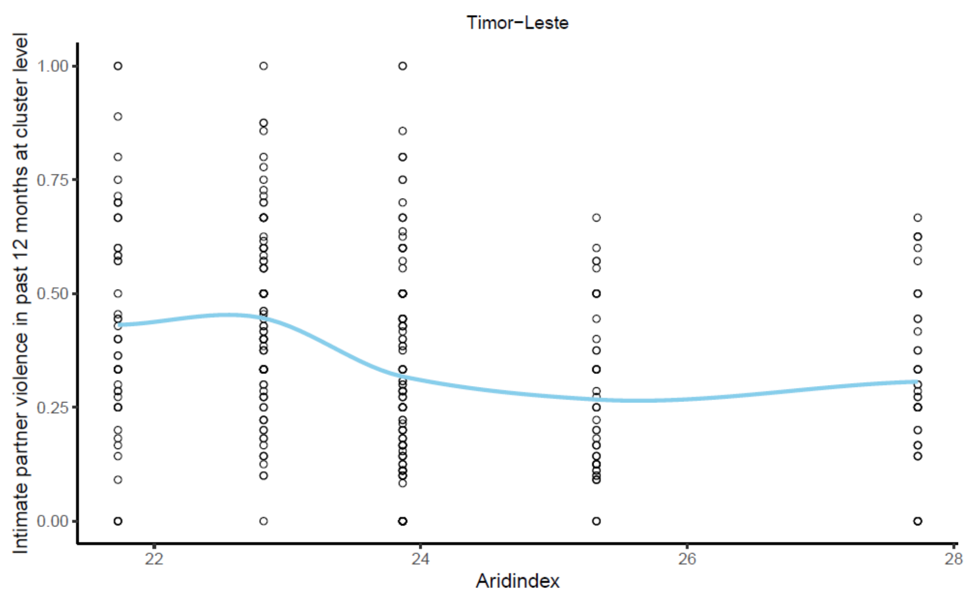


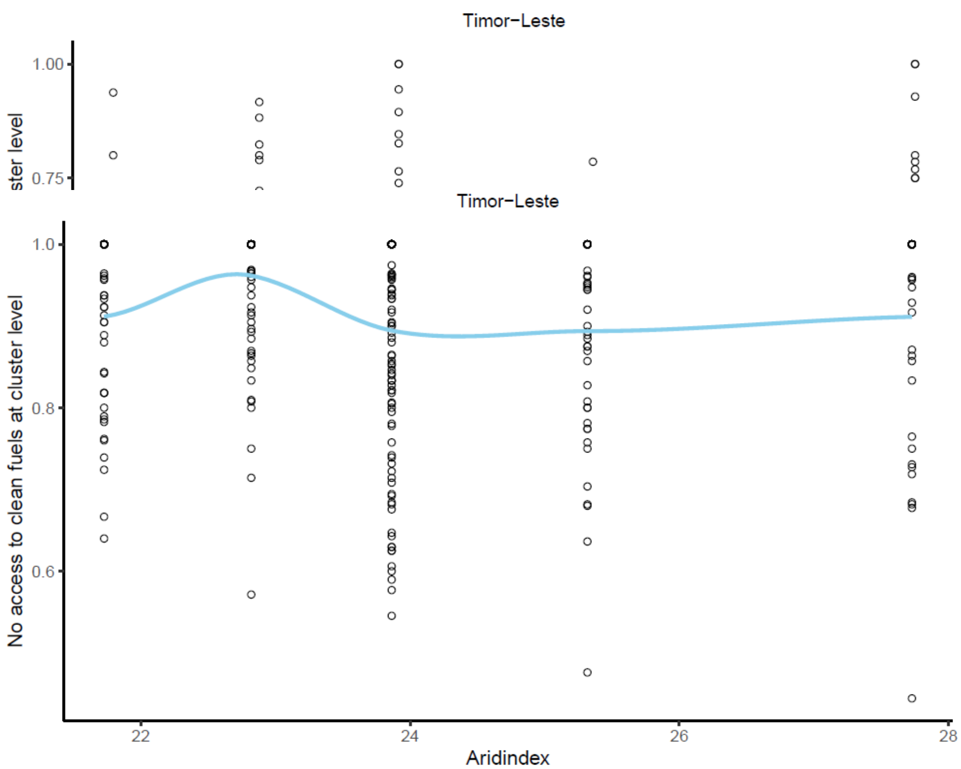

Philippines
Intimate partner violence in past 12 months at cluster level
0.5
0.4
0.3
0.2
0.1
0.0
25
30
35
Day land surface temperature


Philippines
No access to basic water at cluster level
1.00
0.75
0.50
0.25
0.00
25
30
35
Day land surface temperature

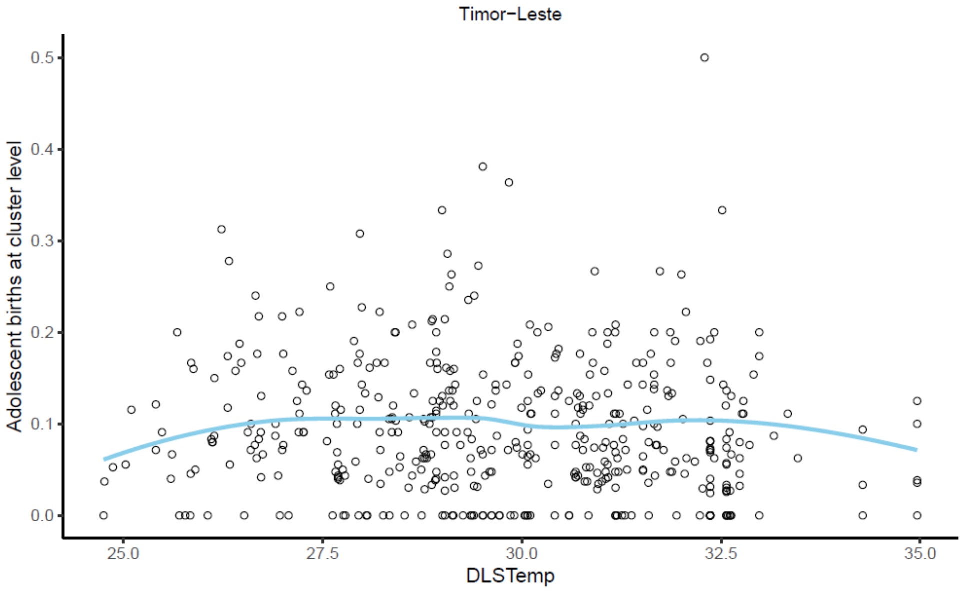


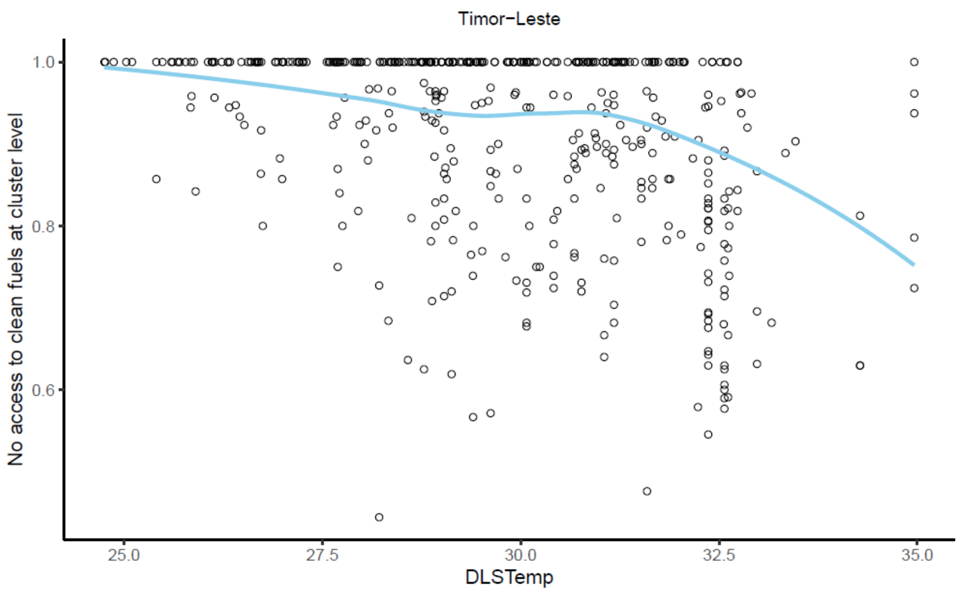
Timor-Leste (Aridity index)





Timor-Leste (Day land surface temperature)


Timor−Leste
Adolescent births at cluster level
DLSTemp
0.0
0.1
0.2
0.3
0.4
0.5
25.0
27.5
30.0
32.5
35.0


Timor−Leste
No access to clean fuels at cluster level
DLSTemp
0.6
0.8
1.0
25.0
27.5
30.0
32.5
35.0

Annex 5: Logistic regression estimates for the effects of climate related factors on the likelihood of gender inequality outcomes

Tables in this annex provide the logistic regression for gender related development indicators for the climate related variables and control variables used in the analysis.

An asterisk indicates significance codes as follows: One asterisk (*) = 0.01. Two asterisks (**) = 0.001. Three asterisks (***) = 0

Due to multicollinearity concerns, some climate related variables were excluded from the analysis: "Proximity to national border" for Timor-Leste and the Philippines and "Rainfall" for Bangladesh.

Due to data availability issues, the climate related variable "Drought episode" was not considered for Timor-Leste and the gender related development indicator "Intimate partner violence" was not considered for Bangladesh.

TABLE A5.1: Logistic regression estimates for the effects of factors related to climate change on the likelihood of child marriage

Variable	Model 1 (unadjusted odds ratio)	Model 2 (adjusted odds ratio)
Drought episode		
Bangladesh	1.055***	1.036***
Cambodia	1.092***	1.067*
Nepal	0.942	1.02
Philippines	1.082***	0.987
Timor-Leste	N/A	N/A
Aridity index		
Bangladesh	0.991***	0.985***
Cambodia	0.992	0.996
Nepal	0.950***	0.977***
Philippines	0.989***	1
Timor-Leste	1.056*	1.03
Rainfall		
Bangladesh	N/A	N/A
Cambodia	1.001***	1.00***
Nepal	1.000	1.000
Philippines	1	1
Timor-Leste	1	1
Day land surface temperature		
Bangladesh	0.892***	1.018
Cambodia	1.046*	1.065**
Nepal	0.995	1.053***

Philippines	0.935***	1.026
Timor-Leste	0.96	1.007
Flood risk		
Bangladesh	1.001***	1.000
Cambodia	1.000	1.000
Nepal	0.999***	0.999
Philippines	1	1
Timor-Leste	1.007	0.989
Proximity to lakes		
Bangladesh	1.000***	1.000***
Cambodia	1.000***	1.000
Nepal	1.000*	1.000*
Philippines	1	1
Timor-Leste	1.000**	1
Proximity to sea		
Bangladesh	1.000***	1.000
Cambodia	1.000	1.000
Nepal	1.000***	1
Philippines	1.000***	1
Timor-Leste	1	1
Location		
Bangladesh		1.152**
Cambodia		1.025
Nepal		1.115*
Philippines		1.202*
Timor-Leste		1.202
Education		
Bangladesh		0.806***
Cambodia		0.872***
Nepal		0.829***
Philippines		0.803***
Timor-Leste		0.904***
Currently employed		
Bangladesh		1.088*
Cambodia		0.999
Nepal		0.99
Philippines		0.879*
Timor-Leste		1.121
Age		

Bangladesh		1.018***
Cambodia		1.001
Nepal		0.986***
Philippines		0.983***
Timor-Leste		0.999
Wealth		
Bangladesh		0.965*
Cambodia		1.009
Nepal		1.028
Philippines		0.788***
Timor-Leste		1.023
Proximity to national borders		
Bangladesh		1.000***
Cambodia		1.000
Nepal		1.000
Philippines		N/A
Timor-Leste		N/A
Proximity to protected areas		
Bangladesh		1.000***
Cambodia		1.000
Nepal		1.000***
Philippines		1
Timor-Leste		1
Built-up index		
Bangladesh		0.634**
Cambodia		0.942
Nepal		0.410***
Philippines		1.286
Timor-Leste		0.522**

TABLE A5.2: Logistic regression estimates for the effects of factors related to climate change on the likelihood of adolescent births

Variable	Model 1 (unadjusted odds ratio)	Model 2 (adjusted odds ratio)
Drought episode		
Bangladesh	1.040***	1.022**
Cambodia	1.079*	1.042
Nepal	0.867***	0.868**

Philippines	1.084**	1.005
Timor-Leste	N/A	N/A
Aridity index		
Bangladesh	0.996***	0.991***
Cambodia	0.984*	0.991
Nepal	0.968***	0.990*
Philippines	0.991***	1.003
Timor-Leste	1.023	0.98
Rainfall		
Bangladesh	N/A	N/A
Cambodia	1.001***	1.001**
Nepal	1.000	1.000*
Philippines	1	1
Timor-Leste	1	0.999*
Day land surface temperature		
Bangladesh	0.940**	1.035
Cambodia	0.99	1.004
Nepal	1.022*	1.040**
Philippines	0.949***	1.038*
Timor-Leste	0.871***	0.910*
Flood risk		
Bangladesh	1.000	1.000
Cambodia	1.000	1.000
Nepal	1	1.001
Philippines	0.998	0.998
Timor-Leste	1.018*	1.004
Proximity to lakes		
Bangladesh	1.000***	1.000***
Cambodia	1.000***	1.000*
Nepal	1.000***	1.000**
Philippines	1	1.000*
Timor-Leste	1	1
Proximity to sea		
Bangladesh	1.000*	1.000***
Cambodia	1.000	1.000
Nepal	1.000**	1
Philippines	1.000*	1
Timor-Leste	1	1
Location		

Bangladesh	1.123**
Cambodia	0.913
Nepal	0.971
Philippines	1.149
Timor-Leste	1.094
Education	
Bangladesh	0.840***
Cambodia	0.849***
Nepal	0.845***
Philippines	0.800***
Timor-Leste	0.887***
Currently employed	
Bangladesh	1.137***
Cambodia	1.143
Nepal	1.037
Philippines	0.967
Timor-Leste	1.109
Age	
Bangladesh	0.997
Cambodia	0.998
Nepal	0.971***
Philippines	0.972***
Timor-Leste	1.002
Wealth	
Bangladesh	0.986
Cambodia	1.02
Nepal	1.038
Philippines	0.857***
Timor-Leste	0.996
Proximity to national borders	
Bangladesh	1.000***
Cambodia	1.000
Nepal	1.000
Philippines	N/A
Timor-Leste	1.000
Proximity to protected areas	
Bangladesh	1.000***
Cambodia	1.000
Nepal	1

Philippines		1
Timor-Leste		0.681
Built-up index		
Bangladesh		0.669*
Cambodia		0.634
Nepal		0.877
Philippines		1.111
Timor-Leste		

TABLE A5.3: Logistic regression estimates for the effects of factors related to climate change on the likelihood of experiencing intimate partner violence in the past 12 months

Variable	Model 1 (unadjusted odds ratio)	Model 2 (adjusted odds ratio)
Drought episode		
Bangladesh	N/A	N/A
Cambodia	0.971	0.902
Nepal	1.207*	1.233*
Philippines	0.977	0.937
Timor-Leste	N/A	N/A
Aridity index		
Bangladesh	N/A	N/A
Cambodia	0.974	0.983
Nepal	0.981*	0.986
Philippines	0.999	1.007
Timor-Leste	0.885***	0.865***
Rainfall		
Bangladesh	N/A	N/A
Cambodia	0.999	0.999
Nepal	1.000	1.000*
Philippines	1.000**	1.000**
Timor-Leste	1.001*	1
Day land surface temperature		
Bangladesh	N/A	N/A
Cambodia	0.921	0.948
Nepal	1.016	1.036
Philippines	0.997	1.073**
Timor-Leste	0.921*	0.928
Flood risk		

Bangladesh	N/A	N/A
Cambodia	0.999*	0.999*
Nepal	1	1.001
Philippines	1	1
Timor-Leste	1.01	1.005
Proximity to lakes		
Bangladesh	N/A	N/A
Cambodia	1	1
Nepal	1.000*	1.000***
Philippines	1	1
Timor-Leste	1	1
Proximity to sea		
Bangladesh	N/A	N/A
Cambodia	1	1
Nepal	1	1
Philippines	1.000*	1.000***
Timor-Leste	1.000*	1
Location		
Bangladesh		N/A
Cambodia		1.081
Nepal		0.888
Philippines		0.896
Timor-Leste		0.948
Education		
Bangladesh		N/A
Cambodia		0.875***
Nepal		0.916***
Philippines		0.945***
Timor-Leste		0.985
Currently employed		
Bangladesh		N/A
Cambodia		0.935
Nepal		1.236
Philippines		1.167
Timor-Leste		0.859
Age		
Bangladesh		N/A
Cambodia		0.994
Nepal		0.967***

Philippines	0.969***
Timor-Leste	0.995
Wealth	
Bangladesh	N/A
Cambodia	0.796***
Nepal	0.870**
Philippines	0.878*
Timor-Leste	0.902**
Proximity to national borders	
Bangladesh	N/A
Cambodia	1
Nepal	1.000
Philippines	1.000
Timor-Leste	N/A
Proximity to protected areas	
Bangladesh	N/A
Cambodia	1
Nepal	1
Philippines	0.454*
Timor-Leste	1
Built-up index	
Bangladesh	N/A
Cambodia	0.918
Nepal	3.566*
Philippines	
Timor-Leste	0.839

TABLE A5.4: Logistic regression estimates for the effects of factors related to climate change on the likelihood of lacking access to basic drinking water sources

Variable	Model 1 (unadjusted odds ratio)	Model 2 (adjusted odds ratio)
Drought episode		
Bangladesh	1.180***	1.184***
Cambodia (dry season)	1.031	0.964
Cambodia (wet season)	1.05	1.107**
Nepal	0.479***	0.667***
Philippines	1.219***	1.047
Timor-Leste	N/A	N/A

Aridity index		
Bangladesh	1.013***	1.000
Cambodia (dry season)	1.030***	1.026***
Cambodia (wet season)	0.982**	0.945***
Nepal	1.025***	1
Philippines	0.985***	1.003
Timor-Leste	1.213***	1.146***
Rainfall		
Bangladesh	N/A	N/A
Cambodia (dry season)	0.999***	0.998***
Cambodia (wet season)	1	1
Nepal	0.999***	1.000
Philippines	1	1
Timor-Leste	1.001***	1.001**
Day land surface temperature		
Bangladesh	0.725***	0.665***
Cambodia (dry season)	0.870***	0.875***
Cambodia (wet season)	0.785***	0.759***
Nepal	1.012	1.122***
Philippines	0.659***	0.771***
Timor-Leste	0.932*	0.989
Flood risk		
Bangladesh	1.001*	1.002**
Cambodia (dry season)	0.998***	0.998***
Cambodia (wet season)	0.996***	0.997***
Nepal	0.999	1.001
Philippines	0.997	0.998
Timor-Leste	1.028***	1.003
Proximity to lakes		
Bangladesh	1.000***	1.000***
Cambodia (dry season)	1.000	1.000***
Cambodia (wet season)	1.000***	1
Nepal	1.000***	1.000***
Philippines	1	1
Timor-Leste	1.000*	1.000*
Proximity to sea		
Bangladesh	1.000***	1.000***
Cambodia (dry season)	1.000***	1.000***
Cambodia (wet season)	1.000	1.000***

Nepal	1	1
Philippines	1.000***	1.000***
Timor-Leste	1	1
Location		
Bangladesh		1.936***
Cambodia (dry season)		2.412***
Cambodia (wet season)		2.063***
Nepal		0.576***
Philippines		1.01
Timor-Leste		1.15
Education		
Bangladesh		1.011
Cambodia (dry season)		0.972***
Cambodia (wet season)		0.957***
Nepal		0.973*
Philippines		0.956***
Timor-Leste		0.988
Currently employed		
Bangladesh		0.969
Cambodia (dry season)		0.899
Cambodia (wet season)		1.005
Nepal		0.992
Philippines		1.290**
Timor-Leste		1.1358***
Age		
Bangladesh		1.005
Cambodia (dry season)		0.992**
Cambodia (wet season)		0.994
Nepal		0.992
Philippines		0.990*
Timor-Leste		0.993*
Wealth		
Bangladesh		0.553***
Cambodia (dry season)		0.544***
Cambodia (wet season)		0.617***
Nepal		0.454***
Philippines		0.501***
Timor-Leste		0.613***
Proximity to national borders		

Bangladesh	1.000***
Cambodia (dry season)	1
Cambodia (wet season)	1.000***
Nepal	1.000***
Philippines	N/A
Timor-Leste	N/A
Proximity to protected areas	
Bangladesh	1.000***
Cambodia (dry season)	1.000***
Cambodia (wet season)	1.000*
Nepal	1
Philippines	1
Timor-Leste	1.000***
Built-up index	
Bangladesh	71.895***
Cambodia (dry season)	0.005***
Cambodia (wet season)	0.004**
Nepal	8.388***
Philippines	0.000***
Timor-Leste	0.068***

TABLE A5.5: Logistic regression estimates for the effects of factors related to climate change on the likelihood of lacking access to clean cooking fuel

Variable	Model 1 (unadjusted odds ratio)	Model 2 (adjusted odds ratio)
Drought episode		
Bangladesh	1.286***	1.186***
Cambodia	0.96	0.787***
Nepal	0.584***	1.076
Philippines	1.503***	1.628***
Timor-Leste	N/A	N/A
Aridity index		
Bangladesh	0.986***	0.959***
Cambodia	1.016**	0.988
Nepal	0.937***	0.971***
Philippines	0.964***	0.993*
Timor-Leste	0.958	0.751***
Rainfall		

Bangladesh	N/A	N/A
Cambodia	1	0.999**
Nepal	0.999***	0.999***
Philippines	1.000***	1
Timor-Leste	1.002***	1
Day land surface temperature		
Bangladesh	0.215***	0.507***
Cambodia	1.097***	1.05
Nepal	0.690***	0.922***
Philippines	0.736***	1.082***
Timor-Leste	0.774***	0.895*
Flood risk		
Bangladesh	1.007***	1.005***
Cambodia	1	1
Nepal	0.998***	1
Philippines	0.998*	0.997*
Timor-Leste	1.054***	1.007
Proximity to lakes		
Bangladesh	1.000***	1.000***
Cambodia	1.000***	1
Nepal	1.000***	1.000*
Philippines	1.000***	1
Timor-Leste	1.000*	1
Proximity to sea		
Bangladesh	1.000***	1.000***
Cambodia	1.000***	1.000***
Nepal	1.000***	1.000***
Philippines	1.000***	1
Timor-Leste	1.000***	1.000***
Location		
Bangladesh		4.1630***
Cambodia		1.457***
Nepal		1.612***
Philippines		2.096***
Timor-Leste		1.258
Education		
Bangladesh		0.959***
Cambodia		0.987
Nepal		0.942***

Philippines	0.971*
Timor-Leste	0.987
Currently employed	
Bangladesh	0.945***
Cambodia	0.726***
Nepal	1.343***
Philippines	0.875*
Timor-Leste	0.97
Age	
Bangladesh	0.995***
Cambodia	0.999
Nepal	0.986**
Philippines	1.012***
Timor-Leste	1.004
Wealth	
Bangladesh	0.152***
Cambodia	0.102***
Nepal	0.184***
Philippines	0.186***
Timor-Leste	0.239***
Proximity to national borders	
Bangladesh	1.000***
Cambodia	1.000***
Nepal	1.000***
Philippines	N/A
Timor-Leste	N/A
Proximity to protected areas	
Bangladesh	1.000***
Cambodia	1
Nepal	1.000***
Philippines	1.000***
Timor-Leste	1
Built-up index	
Bangladesh	0.094***
Cambodia	0.026***
Nepal	0.006***
Philippines	0.016***
Timor-Leste	0.972